Improving Modeling and Mitigation Strategies for Poultry Ammonia Emissions Across the Chesapeake Bay Watershed

STAC Workshop Report
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Virtual Workshop

STAC Publication 26-001

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Cover graphic from: NRCS Practice Code 591: Amendments for the treatment of agricultural waste is the treatment of manure, process wastewater, stormwater runoff from lots or other high intensity areas, and other wastes with chemical or biological additives. Source: NRCS Tennessee.

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Abbreviations and Acronyms

AAPFCO – Association of American Plant Food Control Officials; provides state-level commercial fertilizer sales data.
AMoN – Ammonia Monitoring Network; national network measuring ambient NH_3 concentrations.
AMT – Atmospheric Measurement Techniques journal.
AQMEII – Air Quality Model Evaluation International Initiative; coordinates multi-model evaluations.
BEIS – Biogenic Emission Inventory System; CMAQ's online biogenic emissions module.
BMP – Best Management Practice; management actions to reduce pollution or improve environmental outcomes.
CAST – Chesapeake Bay Assessment Scenario Tool; Chesapeake Bay Program watershed modeling platform for evaluating BMP scenarios and nutrient reductions.
CBP – Chesapeake Bay Program; federal–state–local partnership coordinating watershed restoration.
CBW – Chesapeake Bay Watershed.
CMAQ – Community Multiscale Air Quality Model; national regulatory air quality model used to estimate atmospheric chemistry, transport, and deposition.
CMV – Commercial Marine Vessels; emission sector representing C1–C3 marine engines.
CrIS – Cross-track Infrared Sounder; satellite instrument providing NH_3 retrievals.
EGU – Electric Generating Unit; point sources such as power plants.
EQUATES – EPA Air QUAlity TimE Series project; generates consistent historical air-quality modeling and emissions (2016–2019).
EPA – U.S. Environmental Protection Agency.
Fertilized Row Crops – Emission sector representing NH_3 volatilization from inorganic fertilizer applications.
IGBP – International Geosphere–Biosphere Programme; land-cover classification used in WRF/CMAQ.
ISAM – Integrated Source Apportionment Method; CMAQ module tracking sector- and region-specific contributions to concentrations and deposition.
LGU – Land Grant University; often provides agricultural extension and research support.
MODIS – Moderate Resolution Imaging Spectroradiometer; NASA land-cover dataset.
NADP/NTN – National Atmospheric Deposition Program / National Trends Network; measures wet deposition across the U.S.
NEI – National Emissions Inventory; EPA's national compilation of emissions by sector and state.
NH_3 – Ammonia; a reduced form of nitrogen.
NH_4^+ – Ammonium ion; particulate form of reduced nitrogen.
NH_x – Total reduced nitrogen ($NH_3 + NH_4^+$).
NO_x – Nitrogen oxides ($NO + NO_2$); key precursors to ozone and nitric acid.
$PM_{2.5}$ – Fine particulate matter with diameter $\leq$ 2.5 microns.
STAC – Scientific and Technical Advisory Committee; independent advisory body to the Chesapeake Bay Program.
STAGE – Surface Tiled Aerosol and Gaseous Exchange; CMAQ module for dry deposition.
TAN – Total Ammoniacal Nitrogen ($NH_3 + NH_4^+$) in manure.
USDA – U.S. Department of Agriculture.
WRF – Weather Research and Forecasting model; provides meteorology inputs for CMAQ.

Executive Summary

A series of six technical workshops examined ammonia emissions from poultry houses to support clearer understanding of emission magnitudes, mitigation practices, model representation, and data needs within the Chesapeake Bay watershed. Sessions included presentations from researchers, industry representatives, agencies, and practitioners, and facilitated broad discussion among more than 100 participants nationwide. The workshops explored ammonia mitigation strategies, reviewed available data on poultry house operations, and evaluated how models such as the Community Multiscale Air Quality (CMAQ) system represent poultry-related emissions and atmospheric nitrogen deposition.

CMAQ is a regional air-quality modeling system used nationally to simulate the emission, transport, chemical transformation, and deposition of atmospheric pollutants, including ammonia. Within the Chesapeake Bay Program, CMAQ provides estimates of how ammonia released from poultry houses moves through the atmosphere and where it deposits across the watershed. These deposition estimates are then incorporated into linked hydrologic and water-quality models. As a result, the precision of poultry emission inputs into CMAQ directly influences estimates of nitrogen loads delivered to the Chesapeake Bay and informs evaluations of potential mitigation strategies.

Major Findings

1. **Nitrogen Loads**: Modeling tools indicate that nitrogen loads from poultry houses represent a relatively small proportion (<5%) of overall nitrogen loads delivered to Chesapeake Bay but significant enough to present an opportunity for mitigation efforts aimed at reducing nitrogen levels in the Chesapeake Bay.
2. **Mitigation Strategies**: Various strategies employed by the poultry industry to manage ammonia emissions are regularly implemented including in-house treatments, litter treatments, vegetated buffers, and ammonia capture. These management strategies vary in effectiveness, and significant challenges remain in understanding their efficacy. Specifically, the effectiveness of mitigation efforts that prevent volatilization, or capture ammonia, depends upon the ultimate fate of those loads.
3. **Lack of attention through Chesapeake Bay Restoration**: Current Chesapeake Bay Restoration efforts have not involved ammonia management at a large scale, as very few Best Management Practices (BMPs) targeting ammonia have been reported. Still, Ammonia remains important to the poultry industry and industry-driven initiatives to protect bird health have led to advancements in ammonia mitigation although some of these may only benefit in-house ammonia levels.
4. **Outcomes based proposals**: There have been several proposals to capture ammonia from poultry houses, offering a quantifiable and reliable practice that may be well suited for pay for performance programs. If such programs have the capacity to utilize ammonia waste to offset inorganic fertilizer demand, they may help provide some relief to nutrient mass imbalances. Still, several questions remain about the efficacy and additionality of this approach.

5. **Data regarding poultry waste management**: The partnership's understanding of ammonia emissions from poultry (and other non-point sources) is limited by details regarding poultry house management. Specifically, The partnership currently lacks data about poultry houses that would help characterize efforts to mitigate ammonia in poultry houses.

Key Recommendations

1. There are shared interests between producers and water quality outcomes with regard to the removal of ammonia from poultry houses, and this overlap represent and opportunity to work collaboratively with the agricultural industry to achieve nutrient reductions.
2. In order to track the ammonium management efforts more effectively, more in depth understanding of poultry management efforts is needed. This includes litter amendment type, timing and amount of applications and other house conditions. Further, given that ammonia management is broadly utilized to some extent, and the lack of BMP reporting, a new approach to tracking these loads is needed.

The workshops underscored that tackling ammonia emissions can both support day-to-day poultry operations and reduce nitrogen reaching the Chesapeake Bay. Even though this source represents a small share of total loads, the combination of clear management options, existing industry interest, and potential water-quality gains makes it a practical place to focus near-term pollution-prevention efforts.

Introduction

Current estimates are that roughly one-third of the nitrogen entering the Chesapeake Bay comes from atmospheric emissions (Chesapeake Bay Program n.d.-a). Historically, about two-thirds of that was in the form of nitrogen oxides (NO_x) and one-third as ammonia (Alexander et al. 2001). Improvements in air quality have played a critical role in restoring the Chesapeake Bay (Chesapeake Bay Program 2015). Emissions of NO_x from power plants and vehicles have achieved substantial nitrogen reductions through the Clean Air Act (Eshleman and Sabo 2016). In contrast, ammonia emissions, which are primarily from agricultural sources, have increased over time. Currently the contribution of NO_x and ammonia to the atmospheric load of nitrogen to the Chesapeake Bay are roughly equal, but in the future the contribution from ammonia is expected to exceed that of NO_x (Chesapeake Bay Program 2017; Campbell et al. 2019). A recent study estimating ammonia emissions and deposition from poultry operations on Maryland's Eastern Shore suggests contributions of nitrogen to local waters and the Chesapeake Bay could be substantial (Baker et al. 2020). In addition to exacerbating eutrophication, ammonia is also toxic to highly sensitive freshwater mussels, as evident by recently adopted EPA Criteria. Ensuring that our modeling approaches are accurately estimating this growing source of nitrogen and that mitigation strategies are explored and implemented are key to protecting water quality in the Chesapeake Bay and its tributaries.

Poultry litter additives (e.g., alum), which are principally applied to promote bird health, prevent nitrogen emissions from poultry houses. NRCS has historically provided incentives for the use of these additives, but there is not a current pathway to crediting their use. Further, CBP modeling efforts lack information related to how frequently these additives are used. While improving the effectiveness of litter additives remains an area of emerging research, scientific literature consistently suggests the capacity to dramatically reduce ammonia volatilization (Moore et al. 1996).

Pursuing litter additives as a management strategy has long been contemplated by the partnership. The Chesapeake Bay Program Best Management Practice Reference Guide suggested these "will be available in future editions." However, progress on quantifying these issues is unclear. Maryland and Delaware have set specific goals to achieve litter treatment as part of their Phase III Watershed Implementation Plans, and yet these practices still do not have the capacity to be credited. This workshop will advance these efforts.

A variety of modeling tools are used to estimate livestock ammonia emissions, deposition, and transport to local waters and the Chesapeake Bay. Wet deposition of ammonium is estimated using wet-fall concentration regression models for the Chesapeake Bay watershed (Grim 2017). Regression parameters include precipitation, land-use information, and livestock emissions. The land-use information is derived from the National Land Cover Database (NLCD) (Grim 2017), and livestock emissions are drawn from the National Emissions Inventory (NEI) (U.S. EPA 2015). In both cases, the most recent data currently used in the CBP framework are from the 2011 versions of these databases, and the 2011 NEI uses livestock inventory data from the 2007 U.S. Department of Agriculture Agricultural Census (U.S. EPA 2015). Livestock and poultry production have increased in the region since 2007, raising questions about whether these increases are captured within the current modeling framework. In addition, some have questioned the adequacy of the emissions factors used in the model (Environmental Integrity

Project 2018). The Community Multi-Scale Air Quality (CMAQ) model integrates information on wet deposition and combines it with other modeling approaches, including dry deposition of ammonia, to estimate nitrogen deposition (Campbell et al. 2019). However, there is greater uncertainty in the characterization of agricultural sector ammonia emissions in the 2011 NEI platform compared to NO_x sources, due to fewer in situ observations and emissions monitoring data (Campbell et al. 2019).

This report summarizes a workshop convened by the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) to evaluate these issues. The workshop brought together experts from federal and state agencies, academia, industry, and other organizations to (1) discuss the current modeling approach for ammonia emissions from livestock and poultry operations and determine whether model estimates are adequate or should be improved and, if so, how; and (2) examine the state of science, implementation pathways, and potential producer benefits for mitigation strategies such as poultry litter additives, including how these practices might be represented and credited within the Chesapeake Bay Program. In doing so, the workshop sought to identify key gaps and advance practical options for improving nitrogen management and protecting the Bay's water quality.

Chapter 1. Which management actions influence ammonia?

Several management efforts have the capacity to influence the transport of ammonia from poultry operations. These efforts are of particular interest to producers because of the impact of ammonia upon bird health. Minimizing ammonia emissions may also yield a higher quality poultry litter with higher nitrogen concentrations. This has the potential to have positive implications for end-user litter application and could reduce demand for inorganic fertilizer application.

These efforts offer potential opportunities to prevent nitrogen from reaching waterways, although these effects are complicated. Reduced nitrogen emissions, which are indiscriminately deposited to the landscape, has some clear benefits. However, some of those benefits may be offset. For instance, if ammonia is retained in the litter but the litter is ultimately applied to the landscape, there may not be a substantive effect or could even be an exacerbation. The benefits of managing ammonia upon gross nitrogen transport are likely most profound if increased nitrogen content of litter is accompanied by decreased field inorganic field applications (i.e., if higher quality litter displaces demand for inorganic fertilizer). Benefits may also be achieved if more balanced N:P ratios of litter prevent excess phosphorous application.

Efforts to manage ammonia can occur at various stages of poultry production from dietary inputs (Hunde et al. 2012), litter amendments (Moore et al. 1996), in house treatments (housing or bedding designs) (Brink et al. 2022), air exhaust management (Adrizal et al. 2008) and post-production litter storage (Shah et al. 2014). End user field storage and application also play an important role in N transport. These efforts span a wide variety of costs, planning needs, and impacts to operations. The poultry industry has made significant progress on many of these management factors, particularly those which have the capacity to improve bird health. Practices which may mitigate ammonia transport through mechanisms that are down-process from bird exposure ostensibly provide less of an incentive for action by industry.

A substantial portion of ammonia management in commercial poultry operations occurs through the use of litter amendments designed to reduce volatilization by lowering pH, binding ammonium, or altering microbial activity. Common products used in the region include aluminum sulfate, sodium bisulfate, and other acidifiers and adsorbers, all of which reduce litter pH and suppress the conversion of ammonium to ammonia gas (Timmons, Litter Amendments, STAC Workshop, May 2022). These mechanisms help explain why litter amendments are widely adopted by growers, even though they are seldom reported as Chesapeake Bay Program BMPs.

Recent work in the Chesapeake Bay watershed has begun to document these management actions more systematically. The Virginia Tech Chesapeake Bay commercial poultry production research project, for example, is collecting grower survey data on the use of litter amendments to control ammonia emissions, including product types and frequency of application, along with litter density measurements on stockpiled litter. These data provide an emerging picture of how ammonia-related practices are implemented in commercial operations, beyond what is currently captured in Chesapeake Bay Program BMP reporting.

There are also several new research initiatives that are exploring capture of ammonia (sometimes selectively) as an approach to help prevent emissions and also produce a viable commodity (liquid fertilizer). Some of these initiatives propose to utilize recirculated air and thus prevent ammonia exposure for birds, which is typically an important consideration for producers.

1.1 Chesapeake Bay Program BMPs

The partnership currently includes litter amendments, and biofilters as approved BMPs for nitrogen reductions. Vegetated buffers for purposes of capturing air emissions have not yet been included in modeling efforts.

1.2 Ammonia control practices in the Chesapeake Bay Assessment Scenario Tool (CAST)

To date, reported implementation of litter amendments has occurred at very low levels. This may be due to the fact the producers rarely receive cost-share incentives to manage litter. Over the past 10 years, only Delaware and Maryland have reported these BMPs and have done so at very low levels. Several industry representatives, as a part of this workshop and in other contexts, report that implementation of litter amendments is much higher, but the data is simply not being reported to the Chesapeake Bay Program. Biofilters have also been sparsely reported.

Chesapeake Bay Assessment Scenario Tool (CAST) scenarios were used to evaluate the model's assumptions about nutrient reductions associated with these practices. Litter amendment BMPs alter modeled nutrient loads by reducing modeled air deposition, but they also presume an increase in nitrogen content in the manure within that geographic unit. The net effect of 100 percent implementation of litter amendments corresponds to an estimated reduction of 1.2 million lb N at the edge of tide (Figure 1).

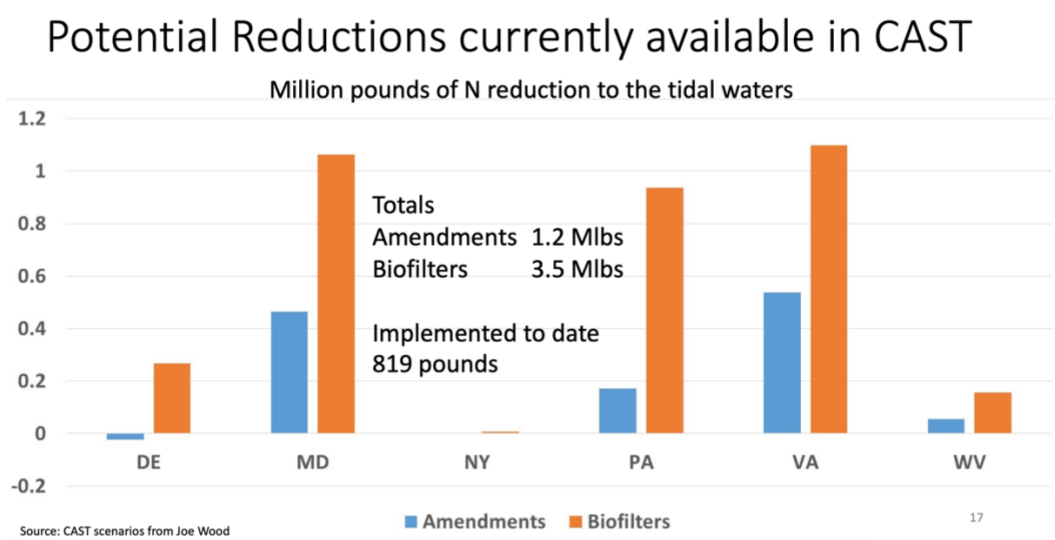

Figure 1. Modeled nitrogen reductions associated with poultry ammonia management practices in the Chesapeake Bay Assessment Scenario Tool (CAST). The scenario compares 0% versus 100% implementation of two approved BMPs: litter amendments and biofilters. Litter amendments are estimated to reduce approximately 1.2 million pounds of nitrogen delivered to edge-of-tide conditions, while biofilters are estimated to reduce approximately 3.5 million pounds. Values reflect underlying model assumptions rather than measured reductions.

Biofilters do not include such a manure nitrogen increase, as it is presumed that vegetative material captured in the filter is taken to a landfill rather than land-applied. The difference between a scenario with 0% biofilter implementation and one with 100% implementation was evaluated. As shown in Figure 1, the net reduction was approximately 3.5 million lb of nitrogen (edge of tide) across the Bay watershed. Given a reduction efficiency of 60%, the current operating assumption of the model is that ammonia from poultry houses accounts for 5.8 million lb of nitrogen delivered to the Bay. By comparison, the model presumes that poultry litter accounts for an additional 13.3 million lb of nitrogen delivered to the Bay. As such, there is a further presumption by the model that roughly one-third of delivered loads from this source are channeled through emissions. These findings are not intended to represent scientific estimates of actual loads, but rather to define the assumptions made by the current model.

1.3 Literature review of management practices

A literature review was conducted to evaluate the effectiveness of these management efforts. Specifically, peer-reviewed publications summarizing costs, ammonia reductions, and other associated benefits were examined. Numerous studies have quantified these metrics individually, but direct comparison among studies is difficult because many influencing factors are not held constant.

The findings from this review are presented here to provide a broad overview of the potential effectiveness of these practices. Several emerging research initiatives that are still in early phases are also described, along with remaining challenges and potential benefits and opportunities associated with these efforts.

Effectiveness of Litter Amendments

Poultry litter amendments are essential for controlling ammonia levels in poultry houses, enhancing bird health and environmental quality. Common amendments include acidifiers such as aluminum sulfate and sodium bisulfate, which lower litter pH to reduce ammonia volatilization (Chai and Ritz 2022). Alkaline materials such as ag lime are used less frequently due to their potential to increase ammonia emissions. Adsorbers, including zeolite and diatomaceous earth, physically or chemically bind ammonia, reducing its release. Inhibitors such as dicyandiamide prevent the conversion of urea to ammonia, although they can be costly. Additionally, microbial and enzymatic treatments are employed to immobilize ammonia by converting it into microbial biomass. Each type of amendment offers distinct benefits and challenges, contributing to a comprehensive approach to ammonia management in poultry production.

Findings from workshop presentations also highlighted how amendment performance varies with pH, moisture content, temperature, and nitrogen concentration in the litter (Timmons, STAC Workshop, May 2022). These factors differ substantially across houses and even across flocks within the same facility, contributing to the wide range of emission reductions reported in the literature.

A review of 13 papers focused on litter amendments found a high degree of variability in amendment effectiveness, with reported reductions ranging from 5% to 95% of emissions (Figure 1). This variability occurred within and between amendment types and across the growing season. Some studies also documented bird health benefits, reduced fuel consumption, lower CO_2 emissions, and reduced phosphorus runoff. A review of six papers focused on feed amendments reported 11–39% ammonia reductions. Six studies on in-house treatments found 6–32% reductions in ammonia, and six studies on exhaust treatments reported 9–99% reductions in ammonia, one of which also demonstrated reductions in particulate matter in exhaust.

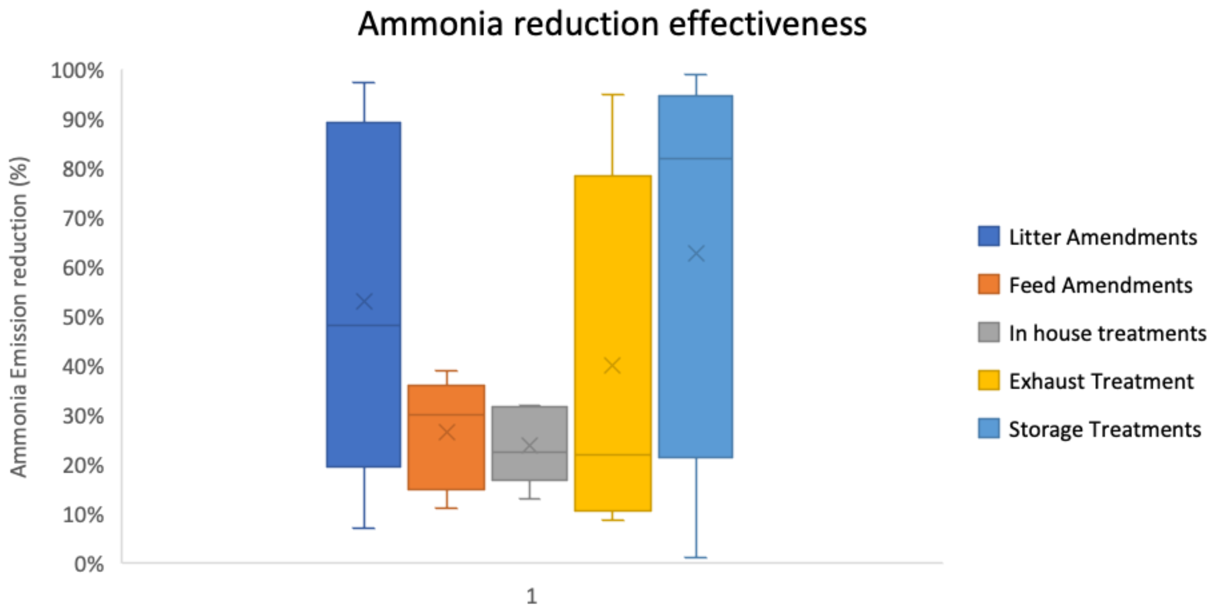

Figure 2. Ammonia emission reductions across various practice types.

Peer-reviewed literature was used to gauge the effectiveness of various practices at reducing ammonia emissions. Several confounding factors make interpretation of these results challenging, including differences in stage of measurement, climate, chemical and physical conditions, and measurement methods, among others. These factors are important to consider when interpreting the reported reductions. Across the literature, a wide range of effectiveness was observed both across and within treatment types, reflecting the many drivers of uncertainty. Collectively, these studies suggest that estimating practice performance in the absence of direct measurements is highly uncertain.

Emergent solutions associated with ammonia capture

Participants discussed several initiatives to improve house air quality by capturing ammonia, which can be utilized as a beneficial byproduct. If these approaches are successful, there are several potential benefits. First, capturing ammonia presents an opportunity to accurately gauge performance as the by-product could be measured and quantified. Given the high level of variability in measured effects for this source as well as others, an opportunity to gauge effectiveness is important. Second, if successful, these efforts may provide a valuable opportunity for producers to adopt a practice with environmental benefits that generates a commodity (Ammonia Fertilizer). Still, challenges associated with these efforts remain. Ensuring technology has the capacity to achieve results is a critical first step. Ensuring this technology can be incorporated into the complex poultry operation is also a significant challenge. Still several initiatives within and throughout the watershed are advancing on these initiatives.

In summary, the transport of ammonia emission from poultry houses to the Chesapeake Bay exists along a long, convoluted trajectory. The overall source is small but not insignificant. Still, this may represent an important opportunity for innovation and pollution reductions given that industry's interests are aligned with mitigating ammonia. Currently, Bay initiatives have not significantly supported this type of management.

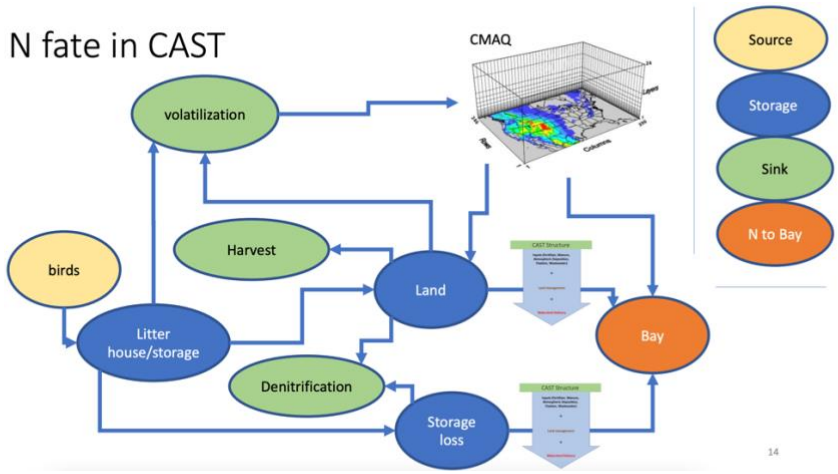

Figure 3. Conceptual diagram showing how poultry-derived nitrogen moves through manure, volatilization, deposition, land application, and delivery to the Bay. Source: Gary Shenk, Poultry Sources in Chesapeake Bay Program Nitrogen Modeling (STAC presentation).

1.4 Findings

Finding 1

One finding is that Effectiveness of these amendments can be highly variable, within and across practice types. Many factors likely contribute to this uncertainty including changing physical conditions, variety of amendments choices, climate, among other varying factors and yet the partnerships modeling tools (CAST) capture very little of this variability. Further the partnership does not currently have data inputs related to how ammonia is managed. The enhanced understanding of these problems might be beneficial for reducing ammonia emissions as well as enhancing poultry production efficiency.

Finding 2

Loads associated with ammonia are presumed by CAST modeling tools to be small but not insignificant, representing 1-5% of agricultural loads. Still, the management of ammonia has clear benefits for poultry producers, can be measured, and may represent a rich opportunity for innovation particularly for the poultry industry.

1.5 On-Going Research and Emerging Technologies

Research universities, public institutions, and private companies conduct research and development in search of new and better technologies and BMPs to reduce or eliminate ammonia. One emergent approach is to attempt to capture ammonia from recirculating air whereby reductions are reduced, bird health is protected and a end-use fertilizer commodity. If this fertilize could offset the need for additional inorganic fertilizer supply it would yield additional benefits for water quality. There are several pilots and research initiatives underway focused around these types of efforts. One significant benefit to this approach from the context of protecting water quality, is the performance of these efforts could be assured through accounting of what is captured.

Chapter 2. Modeling Ammonia Emissions within the Chesapeake Bay Watershed

Air quality has been an important component in understanding Chesapeake Bay nutrient loads. Significant changes in oxidized nitrogen have been a fundamental factor leading to reduced nitrogen loads. Understanding of these loads is informed by closely tracked point sources (air) and by characterization of vehicle emissions. Other sources of atmospheric nitrogen, such as agriculture, have historically received less attention. This chapter summarizes efforts to quantify atmospheric sources of nitrogen through the Chesapeake Bay Model, as well as through the Community Multiscale Air Quality (CMAQ) model.

2. Methods

2.1 Atmospheric Model Description

Numerical air-quality models simulate emissions to the atmosphere and their subsequent chemistry, transport, and fate. The Community Multiscale Air Quality (CMAQ) model is a process-based model that relies on physical and chemical first principles, rather than calibration to specific applications, to predict concentrations of airborne gases and particles and their deposition to Earth's surface. Because CMAQ represents emissions and the properties of individual compounds and classes of compounds, it can also describe the chemical composition of pollutant mixtures. This capability is particularly useful when measurements provide only aggregate information, such as total nitrogen deposition.

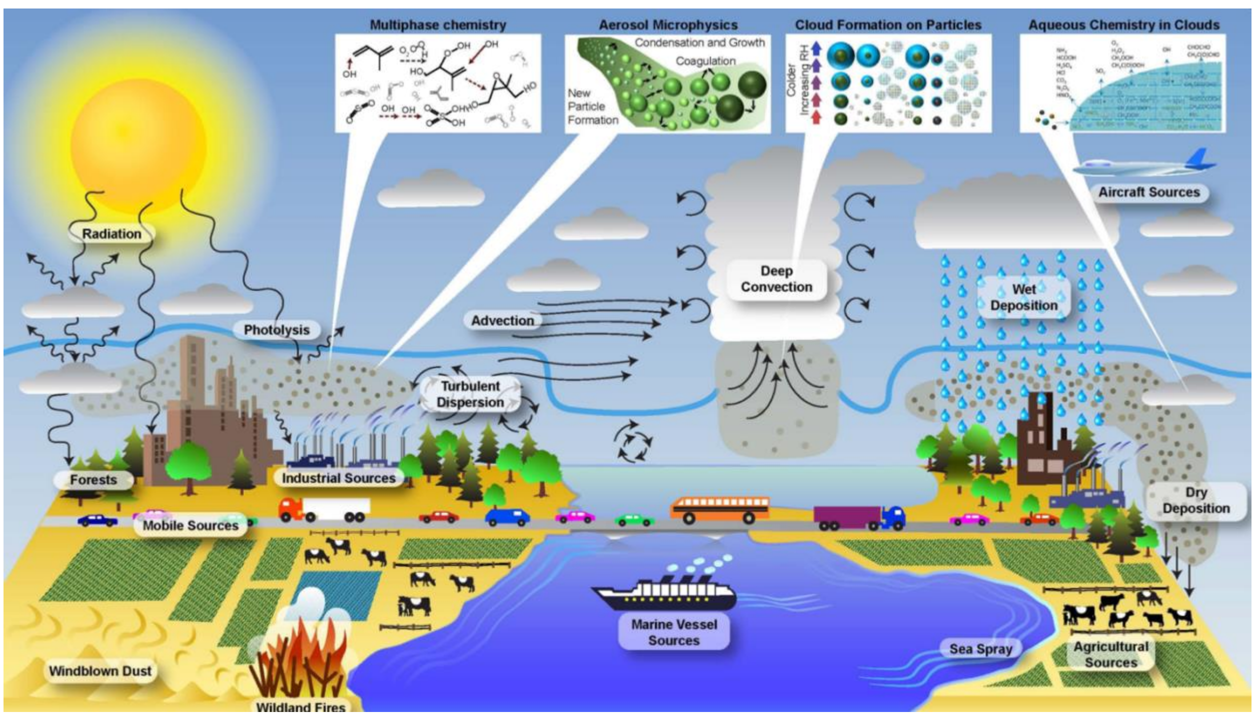

Figure 4. Conceptual overview of the atmospheric processes represented in the CMAQ model, including emissions from major source sectors, chemical transformation, transport, and wet and dry deposition. An interactive version of this figure and additional process descriptions are available on the U.S. Environmental Protection Agency website: https://www.epa.gov/cmaq/overview-science-processes-cmaq

The purpose of CMAQ is to provide fast, scientifically robust estimates of ozone, particulate matter, air toxics, and acid and nutrient deposition. CMAQ is designed to meet the needs of both the scientific community and decision-makers by integrating current knowledge in atmospheric science and air-quality modeling with advanced multi-processor computing and an open-source framework within a single modeling system.

2.2 Description of Model simulations

The Integrated Source Apportionment Method (ISAM) in CMAQ was first implemented in CMAQ version 4.7.1 (Kwok et al. 2013) and updated in version 5.0.2 (Kwok et al. 2015) and version 5.3 (Appel et al. 2021). The ISAM calculates source attribution for user-specified ozone and particulate matter precursors directly in CMAQ. An input control file allows users to specify a variety of species, emission sectors, and source regions of interest. Source attribution can be mapped directly to emission sectors (e.g., mobile, biogenic, lightning, etc.) and/or geographically (e.g., by state, province, or other user-defined region). Similar to other source apportionment techniques, the ISAM also tracks contributions from lateral boundary conditions, initial conditions, and untracked categories (termed "Other") to account for any remaining emissions and to maintain mass balance. While previous ISAM updates heavily leveraged previous model versions, the revised module in CMAQv5.3.2 includes substantial updates to the gas-phase chemistry (Hutzell and Napelenok 2021, Shu et al., 2023) and dry deposition (Napelenok and Bash 2021). CMAQ ISAM modeling tools have been employed to estimate the source contribution of emissions to ambient concentration in Baltimore, MD (Simon et al. 2018). Here, CMAQ model version 5.3.2 with ISAM is applied to reduced (NH_3 and aerosol NH_4) and oxidized (NO, NO_2, HNO_3, organic nitrates, aerosol NO_3, and aerosol organic nitrogen) nitrogen species for the 2016 calendar year to assess emission-source contributions to nitrogen deposition.

CMAQv5.3.2–ISAM simulations for model year 2016 were completed for the Northeastern US (Figure 5) using 12 km grid spacing (111 rows and 103 columns) and 35 vertical layers. Anthropogenic emission inputs were based on the 2017 National Emission Inventory (NEI) and biogenic emissions were calculated online using the Biogenic Emission Inventory System (BEIS; Bash et al. 2016), following methods used in the EQUATES (https://www.epa.gov/cmaq/equates; Benish et al. 2022) simulations. In late 2021, EPA was notified that Maryland animal NH_3 emissions from the 2017 NEI provided by the state were substantially different from previous NEI data due to accounting errors, and these emissions were corrected for the CMAQ–ISAM simulations and subsequent analysis in this report unless otherwise noted. Meteorological inputs were generated from the Weather Research and Forecasting (WRF) model version 4.1.1, and lateral boundary conditions were provided by the EQUATES simulations (Benish et al. 2022). The Surface Tiled Aerosol and Gaseous Deposition (STAGE) option in CMAQ v5.3.2 (Galmarini et al. 2021) was used to estimate atmospheric dry deposition rates.

Emission sectors and geographical regions used in these CMAQ v5.3.2 ISAM simulations were selected based on feedback from the Chesapeake Bay Program Modeling Workgroup. Six emission sectors were chosen based on the ability of state and federal governments to regulate emissions from each sector, as well as their potential to inform future management decisions in currently unregulated emission sectors. Point-source sectors represented include electricity-generating units (EGUs) and commercial marine vessels (CMVs, C1–C3), and the area sources comprise nonroad, mobile, manure sources from poultry, and manure from all other animals. Selected source regions, shown in Figure 5a, represent major NH_3 emission sources within the CBW states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia). For example, emissions from the Delmarva and Central West regions, including Shenandoah Valley, are dominated by the large and growing agricultural sector, particularly poultry. The Central Piedmont region of Maryland is impacted by urban emissions from Baltimore and Washington, D.C., such as mobile and other industrial sources. In addition to regions labeled in Figure 5a, emissions originating from outside the CBW states but inside the Northeastern US modeling domain are tracked as an additional source region, referred to throughout this paper as the region outside the CBW states. Due to the larger 12 km grid spacing, masks for the source regions were developed based on area contribution to each grid cell; for example, if a grid cell spans more than one region, source contributions are estimated using the fraction of the grid cell in each region.

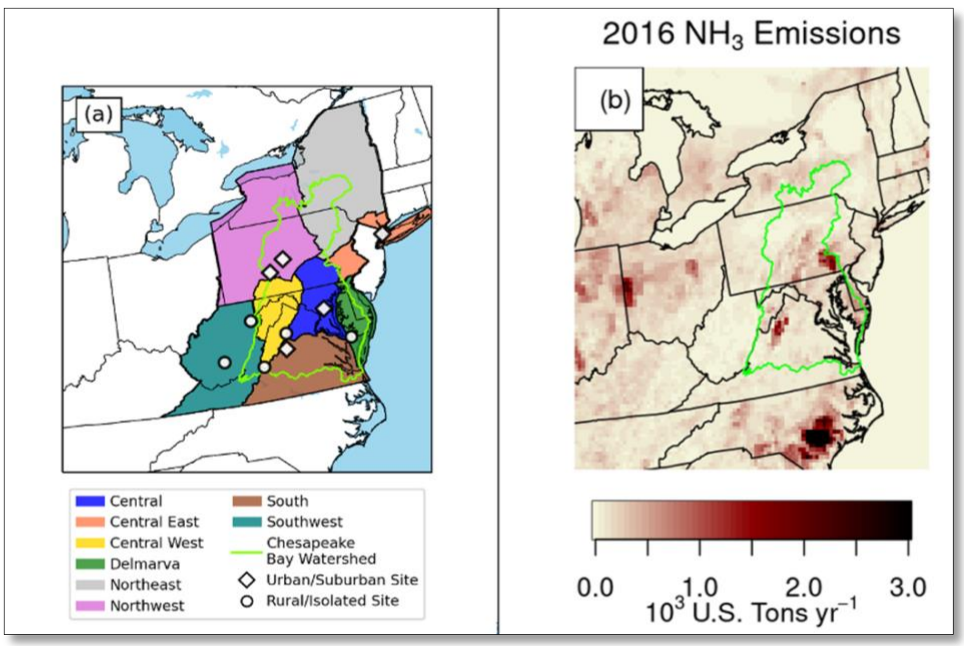

Figure 5. (A) Computational domains and source-apportionment regions used in this study. Named source regions encompass the six Chesapeake Bay watershed States (Maryland, Virginia, West Virginia, New York, Delaware, and Pennsylvania). The area inside the computational domain but outside these regions is referred to as the region outside the watershed States. National Atmospheric Deposition Program (NADP) National Trends Network (NTN) measurement locations are shown as diamonds (urban or suburban locations) and circles (rural or isolated locations). (B) Annual NH_3 emissions from the U.S. Environmental Protection Agency (EPA) 2017 National Emissions Inventory (NEI) with the corrected Maryland animal emissions.

Chapter 3. Results

3.1 Emission Estimates

The emissions used in the CMAQ–ISAM simulation are based on the U.S. EPA's Air QUAlity TimE Series (EQUATES) project (https://www.epa.gov/cmaq/equates). EQUATES relies on the 2017 National Emissions Inventory (NEI) as its base year. For each emissions sector in the 2017 NEI, one of four approaches was used to generate emissions for the 2016 ISAM simulation:

- Developing new methods to create consistent emissions across all years
- Using 2017 NEI emissions with scaling factors based on activity data and/or emissions control information—this approach was applied to agricultural, mobile, fire, and EGU emissions
- Keeping emissions constant at 2017 NEI levels

A high-level summary of the approach applied to each sector is provided in Foley et al. (2020). As noted in the previous section, NH_3 emissions from the Maryland animal sector originally reflected an earlier draft of the 2017 NEI due to an error in the final NEI submission. These draft emissions were more consistent with NEI estimates from earlier years (e.g., 2011 and 2014).

Total NH_3 emissions entering the modeling domain (representing the approximate airshed) were estimated at 1,633,829 U.S. tons. Of this total, 420,986 tons originated within the states included in the ISAM source regions, and 221,208 tons were emitted within the Chesapeake Bay Watershed (Tables 1 and 2). Unless otherwise noted, emissions and deposition values are reported in U.S. tons for the identified ISAM region or the full modeling domain.

Table 1. NH_3 emissions by region and sector in U.S. Tons for 2016 in the ISAM modeling domain.

Sector/Region	*Manure*	*Poultry*	*Mobile*	*Fertilizers*	*EGU*	*CMV*	*Untracked Sector*	*All Sectors*
Central	35,848	11,557	6,191	8,561	-	2	4,906	67,065
Central East	9,665	3,307	8,202	4,460	10	9	5,547	31,199
Central West	19,167	28,642	1,271	7,678	-	-	1,006	57,764
Delmarva	3,949	25,600	1,184	4,763	-	2	641	36,139
Northeast	41,924	3,321	3,502	19,113	-	1	5,858	73,718
Northwest	47,897	5,674	4,359	20,007	-	1	5,683	83,622
South	16,047	5,560	3,446	10,689	27	4	2,475	38,249
Southwest	12,176	2,209	2,406	13,193	-	1	3,245	33,230
Outside Watershed States	591,557	173,746	45,174	258,423	4	12	143,928	1,212,843
Total	778,229	259,615	75,736	346,888	41	32	173,289	1,633,829

Table 2. NH_3 emissions by region and sector in U.S. Tons for 2016 and the Chesapeake Bay Watershed.

Sector/Region	*Manure*	*Poultry*	*Mobile*	*Fertilizers*	*EGU*	*CMV*	*Untracked Sector*	*All Sectors*
Central	35,187	11,281	6,178	8,513	-	2	4,891	66,052
Central East	3,038	1,036	72	371	-	-	46	4,562
Central West	17,112	28,615	1,173	6,702	-	-	922	54,524
Delmarva	3,031	19,588	543	3,766	-	1	323	27,251
Northeast	11,718	1,207	915	4,054	-	-	857	18,751
Northwest	17,077	4,280	729	4,622	-	-	831	27,540
South	6,548	3,846	2,749	5,259	-	4	1,887	20,292
Southwest	721	566	101	807	-	-	40	2,235
Total	94,432	70,418	12,460	34,095	-	7	9,796	221,208

3.2 Evaluation Against Monitoring Network and Satellite Observations

CMAQ v5.3 has been extensively evaluated against air-quality monitoring networks, including the Ammonia Monitoring Network (AMoN; Appel et al. 2021). Results from the EQUATES project have also been evaluated against National Atmospheric Deposition Program (NADP) wet-deposition observations and Clean Air Status and Trends Network (CASTNet) ambient-concentration observations (Benish et al. 2022). The emissions updates applied here did not substantially change these previously published findings, likely because of the spatial sparsity of NH_3 and NH_4 ambient-concentration and wet-deposition measurements across the modeling domain (Figure 5a).

In the states draining to the Chesapeake Bay, this CMAQ simulation underestimated annual mean NH_3 concentrations at AMoN sites by approximately 0.4 ppbv (48.8%) and underestimated annual total wet deposition of NH_x ($NH_3 + NH_4$) at NADP/NTN sites by approximately 0.21 lb acre^{-1} (22%). The model underestimate of gaseous NH_3 in 2016 may be partially offset by an overestimate of mean annual aerosol NH_4 concentrations of approximately 21.1% (equivalent to 0.06 ppbv), indicating that the model places a larger fraction of total NH_x in particulate form than is observed over the Chesapeake Bay states.

Recent advances in space-based observing systems have resulted in the availability of high-quality satellite observations of near-surface ammonia (Shephard and Cady-Pereira 2015; Shephard et al. 2020). CMAQ ambient NH_3 estimates evaluated against Cross-track Infrared Sounder (CrIS) satellite observations show a similar mean bias over the Chesapeake Bay airshed, with a mean bias of −0.37 ppbv, which is near the CrIS detection limit (Shephard et al. 2020). However, these observations provide a more complete picture of CMAQ performance: CMAQ estimates in agricultural areas are generally close to CrIS-retrieved values (with the exception of overestimates of NH_3 in agricultural regions of North Carolina and western Ohio) and show close spatial agreement (Figure 6).

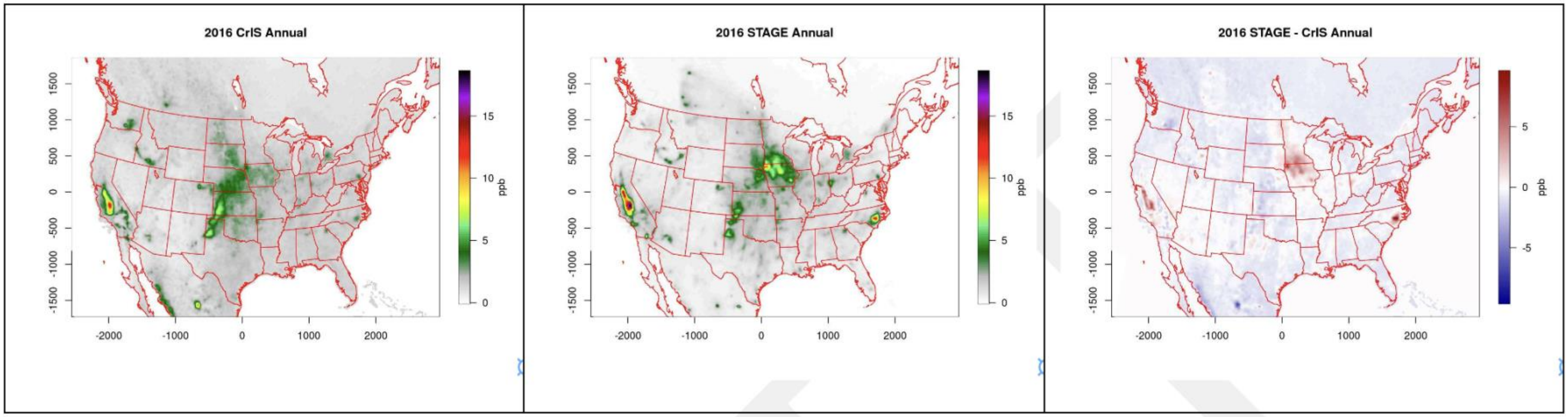

Figure 6. 2016 annual mean midday surface layer NH3 observations of Cross-track Infrared Sounder (CrIS) satellite observations of tropospheric ammonia for the Chesapeake Bay Airshed (a), annual mean 2016 CMAQ NH3 estimates paired in space and time with the CrIS observations, mean 2016 CMAQ – CrIS surface observations the white areas of the plot approximately correspond to the 0.3 to 0.5 sampling bias in the CrIS observations (c).

3.3 Sector and Region Contribution to Atmospheric Nitrogen Deposition

Total nitrogen and NH_x ($NH_3 + NH_4^+$) deposition were tabulated for the Chesapeake Bay watershed and Chesapeake Bay tidal waters for the 2016 annual simulation. Tidal waters are defined as grid cells in which the WRF-expanded MODIS International Geosphere–Biosphere Programme (IGBP) land-cover classification (Broxton et al. 2014) indicates greater than 5% surface-water coverage at 12 km resolution.

Annual 2016 CMAQ model estimates of total nitrogen deposition to the Chesapeake Bay watershed and tidal waters are 280,181 and 36,663 U.S. tons of nitrogen, respectively (Tables 3 and 4). The corresponding estimates of NH_x deposition are 127,181 and 16,045 U.S. tons of nitrogen, respectively (Tables 5 and 6). The fraction of NH_x deposition relative to total nitrogen deposition is 45.4% for the Chesapeake Bay watershed and 43.8% for tidal waters.

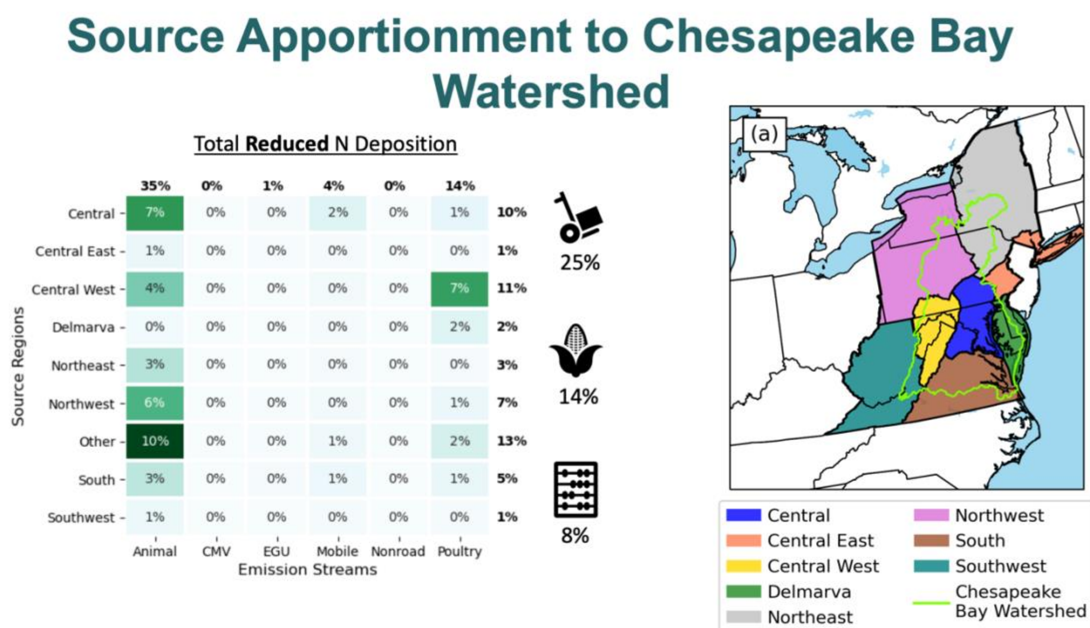

Figure 7. CMAQ v5.3.2 Integrated Source Apportionment Method (ISAM) modeling domain for the Northeastern United States, showing the 12-km grid and the Chesapeake Bay watershed States (Maryland, Virginia, West Virginia, Delaware, Pennsylvania, and New York). National Atmospheric Deposition Program (NADP) National Trends Network (NTN) monitoring locations are shown as diamonds (urban or suburban sites) and circles (rural or isolated sites). The area inside the modeling domain but outside these States is treated as the "outside CBW States" source region. Figure adapted from Benish, S.E. et al. 2022, Atmospheric Chemistry and Physics, v. 22, p. 12749–12772, https://acp.copernicus.org/articles/22/12749/2022/acp-22-12749-2022.pdf This analysis was completed before the 2017 NEI emissions error was identified. Updated values for the Central West, Central, and Delmarva regions are in Tables 3-6.

Emissions sectors were modeled as manure (all animal production except poultry), poultry (layers, broilers, turkeys, ducks, etc.), mobile (on- and off-road gas and diesel vehicles), electric generating utility (EGU) point sources, commercial marine vessels (CMV), fertilized row crops, and boundary conditions. Manure, poultry, mobile, EGU, and CMV emissions were tracked by the nine emission regions in Figure 1a. Model estimates indicate that agricultural sources (manure, poultry, and fertilizers) made the largest contribution to NH_x and total nitrogen atmospheric deposition in the Chesapeake Bay watershed and tidal waters, followed by emission sources outside the Chesapeake Bay airshed (boundary conditions), Tables 3–6. Emissions from mobile sources were the third largest sector contribution to total nitrogen atmospheric deposition, Tables 3 and 4, while untracked sectors were the third largest contribution to NH_x deposition, Tables 5 and 6.

Table 3. CMAQ estimated total nitrogen atmospheric deposition (U.S. Tons of N) by sector and area to the Chesapeake Bay Watershed or 2016.

Region	*Manure*	*Poultry*	*Mobile*	*EGU*	*CMV*	*Fertilizers*	*Untracked Sector*	*Boundary Conditions*	*Total*
Central	8,495	2,605	12,836	2,317	921	-	-	-	27,174
Central East	862	297	4,085	1,070	730	-	-	-	7,044
Central West	5,478	8,694	4,559	505	-	-	-	-	19,235
Delmarva	705	4,646	2,320	232	795	-	-	-	8,697
Northeast	3,494	386	3,280	550	102	-	-	-	7,812
Northwest	6,694	1,383	6,722	4,113	378	-	-	-	19,290
South	3,167	1,457	6,624	1,889	729	-	-	-	13,866
Southwest	853	285	2,744	2,413	206	-	-	-	6,502
Other	11,042	3,368	15,450	3,954	1,832	-	-	-	35,646
Not Tracked by Area	-	-	-	-	-	16,559	49,500	68,855	134,915
Total	40,790	23,119	58,622	17,043	5,693	16,559	49,500	68,855	280,181

Table 4. CMAQ estimated total nitrogen atmospheric deposition (U.S. Tons of N) by sector and area to the Chesapeake Bay tidal waters for 2016.

Region	*Manure*	*Poultry*	*Mobile*	*EGU*	*CMV*	*Fertilizers*	*Untracked Sector*	*Boundary Conditions*	*Total*
Central	962	297	2,271	442	283	-	-	-	4,254
Central East	73	23	584	169	113	-	-	-	961
Central West	216	268	303	55	-	-	-	-	842
Delmarva	191	1,139	641	49	262	-	-	-	2,282
Northeast	140	12	230	45	12	-	-	-	439
Northwest	337	88	527	382	37	-	-	-	1,370
South	626	158	1,464	424	346	-	-	-	3,018
Southwest	72	16	261	234	20	-	-	-	603
Other	2,191	628	1,977	475	289	-	-	-	5,559
Not Tracked by Area	-	-	-	-	-	2,010	6,808	8,517	17,335
Total	4,808	2,630	8,256	2,273	1,362	2,010	6,808	8,517	36,663

The largest contributions of the tracked source regions were from emissions from the airshed for both NH_x and total nitrogen atmospheric deposition, indicating that transport of reactive nitrogen from outside the Chesapeake Bay watershed states makes a non-negligible contribution to nitrogen loading in the Chesapeake Bay watershed and its tidal waters. The Central region (including the Washington, D.C. megalopolis; Figure 5a) had the highest contribution to total nitrogen atmospheric deposition to the Chesapeake Bay watershed and tidal waters (Tables 3 and 4) of the tracked regions within or partially within the Chesapeake Bay watershed. The regional contributions of NH_3 emissions to NH_x deposition differed from the total nitrogen allocation due to the more rapid removal of NH_3 from the atmosphere than emitted NO_x. The Central West regional emissions were estimated to have the highest contribution of NH_x deposition to the Chesapeake Bay watershed (Table 5). In the Central West region, poultry is modeled as the largest NH_3-emitting source (Table 1) and contributes to the largest tracked deposition in the same region (Table 5). The largest contributors to atmospheric NH_x deposition shift to the Central region, closely followed by the Delmarva source region (Table 6).

This shift is due to the short atmospheric lifetime of NH_3, which has been observed to elevate concentrations and atmospheric deposition from hundreds of feet to several miles downwind of emission sources (Pitcairn et al. 2002; Walker et al. 2008; Jones et al. 2013; Walker et al. 2014; Shen et al. 2016; Yi et al. 2021). In these CMAQ simulations, the downwind distance from an emission source of enriched NH_3 deposition cannot be resolved at scales finer than 12 km (approximately 7.45 miles). Based on these simulations, approximately 30–40% of the NH_3 emissions within the designated emission region are estimated to be deposited in that same region, with the remaining emissions contributing to background ambient atmospheric NH_x concentrations and regional or long-range transport. The highest rates of NH_3 emissions correspond with the highest rates of NH_x deposition, in agreement with recent observations (Pitcairn et al. 2002; Jones et al. 2013; Shen et al. 2016; Yi et al. 2021; Figure 6).

Table 5. CMAQ estimated $NH_3 + NH_4+$ atmospheric deposition (U.S. Tons of N) by sector and area to the Chesapeake Bay Watershed for 2016.

Region	*Manure*	*Poultry*	*Mobile*	*EGU*	*CMV*	*Fertilizers*	*Untracked Sector*	*Boundary Conditions*	*Total*
Central	8,495	2,605	1,880	142	2	-	-	-	13,123
Central East	862	297	4,085	1,070	730	-	-	-	7,044
Central West	5,478	8,694	4,559	505	-	-	-	-	19,235
Delmarva	705	4,646	2,320	232	795	-	-	-	8,697
Northeast	3,494	386	3,280	550	102	-	-	-	7,812
Northwest	6,694	1,383	6,722	4,113	378	-	-	-	19,290
South	3,167	1,457	6,624	1,889	729	-	-	-	13,866
Southwest	853	285	2,744	2,413	206	-	-	-	6,502
Other	11,042	3,368	15,450	3,954	1,832	-	-	-	35,646
Not Tracked by Area	-	-	-	-	-	16,559	49,500	68,855	134,915
Total	40,790	23,119	58,622	17,043	5,693	16,559	49,500	68,855	280,181

Table 6. CMAQ estimated $NH_3 + NH_4+$ atmospheric deposition (U.S. Tons of N) by sector and area to the Chesapeake Bay tidal waters for 2016.

Region	*Manure*	*Poultry*	*Mobile*	*EGU*	*CMV*	*Fertilizers*	*Untracked Sector*	*Boundary Conditions*	*Total*
Central	962	297	356	28	1	-	-	-	1,644
Central East	73	23	39	23	0	-	-	-	158
Central West	216	268	14	1	-	-	-	-	499
Delmarva	191	1,139	59	5	1	-	-	-	1,395
Northeast	337	88	23	4	0	-	-	-	451
Northwest	6,694	1,383	6,722	4,113	378	-	-	-	19,290
South	626	158	230	66	2	-	-	-	1,081
Southwest	72	16	12	1	0	-	-	-	100
Other	2,191	628	104	17	0	-	-	-	2,940
Not Tracked by Area	-	-	-	-	-	2,010	1,662	3,939	7,611
Total	4,808	2,630	847	145	4	2,010	1,662	3,939	16,045

The annual CMAQ simulation estimated total nitrogen deposition hotspots in the Shenandoah Valley, VA; the Susquehanna Valley near Lancaster, PA; near Baltimore, MD; and in the southern portion of the Delmarva Peninsula (Figure 3b). There are two areas of elevated NH_x deposition from poultry emissions: the highest modeled values occur in the Shenandoah Valley, VA, followed by the Delmarva Peninsula around Somerset County, MD, which correspond to elevated areas of local poultry NH_3 emissions (Figure 2). Due to the tendency of NH_3 to deposit near sources, the CMAQ simulations estimated that the largest source of poultry NH_x deposition to the tidal waters is from sources on the Delmarva Peninsula near Somerset County, MD, where it contributes approximately 30% of the total nitrogen deposition, or 2.2 lb ac^{-1} yr^{-1} (Figure 4). In total, poultry NH_3 emissions were estimated to contribute 7.2% and 16.4% of the total nitrogen and NH_x deposition, respectively, to the Chesapeake Bay tidal waters (Tables 4 and 6).

3.4 Modeling Summary

CMAQ v5.3.2 with the Integrated Source Apportionment Method (ISAM) was run for a 2016 annual simulation covering the Chesapeake Bay airshed (Linker et al. 2000). Model estimates of ambient concentrations (Appel et al. 2021) and wet deposition (Benish et al. 2022) compare well with observations. CMAQ estimates that approximately 75% of the nitrogen deposition in the Chesapeake Bay watershed originates from emissions within the airshed—approximately the extent of the modeled domain in these simulations—in agreement with prior estimates (Linker et al. 2000).

NH_3 emissions and NH_x deposition hotspots are colocated, indicating that areas of elevated NH_x deposition are primarily located near emission sources, consistent with recent measurements (Pitcairn et al. 2002; Jones et al. 2013; Shen et al. 2016; Yi et al. 2021). The modeled and observed spatial heterogeneity in NH_3 concentrations and deposition presents challenges in model evaluation because the location and number of monitoring sites likely influence observed values. CMAQ model estimates and CrIS satellite observations show similar spatial patterns of elevated NH_3 concentrations and may be useful for identifying monitoring locations influenced by large emission sources.

3.5 CAST Sensitivity Test Utilizing Biofilter BMP Reductions

CAST is informed by CMAQ, but also includes efficiencies for BMPs that influence atmospheric transport and delivery. Several CAST reviews were conducted to ascertain the level of impact Bay modeling currently presumes poultry ammonia contributes to Bay loads. These are not direct assessments of emissions and their transport, but rather an indication of the loading that current models presume for these sources.

Back-calculating from BMP Reductions

Two identical scenarios in CAST (details not shown) were constructed with 0% and 100% implementation of biofilters. The difference in delivered load between these two scenarios was then adjusted for the assumed BMP efficiency (60% reduction) to quantify the atmospheric load assumed in CAST. The results suggested that biofilters could reduce delivered loads by 3.5 lb N per year, and thus the presumed total load associated with this source would be 5.8 million lb N.

Literature-based Emission Factors and Estimates of Animals Units

Another approach used to estimate current poultry-related loads involved combining state-level estimates of animal units with presumed deposition rates. This resulted in estimates ranging from 3.8 to 21.1 lb N delivered per year.

Chapter 4. How can the partnership improve our understanding of current commercial poultry production management practices and levels of BMP implementation?

This chapter synthesizes discussions and presentations from the May 4, 2022 STAC workshop session, which was structured around a set of guiding questions posed to the Chesapeake Bay Program partnership. The session opened by asking: (1) what sources and data collection methods are currently available for representing commercial poultry production management practices related to ammonia generation and mitigation; (2) whether additional financial and technical resources should be invested to collect these data; (3) which commercial best management practices (BMPs) for reducing ammonia emissions warrant routine tracking; (4) how frequently such data should be collected; and (5) what obstacles limit implementation and reporting. An initial overview described the existing poultry ammonia emissions data and how they are represented in the Chesapeake Bay Watershed Model (CBWM) and Chesapeake Assessment Scenario Tool (CAST), followed by a series of scientific presentations on commercial production trends, ammonia emissions, litter amendment use, and ongoing poultry data research in the Bay watershed.

Subsequent panel discussion and group dialogue, including interactive Mentimeter polling, focused on identifying critical knowledge gaps, obstacles to developing and integrating new commercial poultry production and mitigation data, and the role of the partnership in addressing these needs. The material summarized in this chapter reflects both the scientific information presented and the perspectives of workshop participants on data priorities, BMP tracking, and the investments needed to improve representation of commercial poultry management and ammonia mitigation in Bay-wide assessment and modeling tools.

4. 1 Summary of Presentations

- "*Current Poultry Trends on Delmarva*" – linked slides
  Dr. Jon Moyle – Poultry Extension Specialist,
  Lower Eastern Shore Research and Education Center (LESREC),
  University of Maryland

As summarized in Figure 8, poultry production on the Delmarva Peninsula has become more consolidated and intensive over the past two decades. The total number of chickens has decreased by 3.4%, while the total liveweight produced has increased by 35%, and housing capacity has increased by 7.8%, despite a 13.9% reduction in the number of chicken houses and a 45.8% decline in the number of growers. These trends indicate a shift toward fewer, larger operations with more advanced housing technology and higher throughput. Over the same period, market weights, feed conversion ratios, and mortality rates have all improved, reflecting greater production efficiency that in turn affects the amount and composition of litter and the potential for nitrogen and ammonia losses from poultry houses and land-applied manure.

Bird Numbers

	1 year change	10 year change	20 year change
567 million chickens	-0.5%	0.7%	-3.4%
4.2 billion pounds of chickens	-0.4%	19%	35%
4,901 chicken houses	-2.7%	8.3%	-13.9%
Housing capacity of **134 million chickens**	-9.8%	13.2%	7.8%
1,361 chicken growers	-1.2%	-13.3%	-45.8%

https://www.dcachicken.com/facts/facts-figures.cfm

UNIVERSITY OF MARYLAND EXTENSION FEARLESS IDEAS

Figure 8. Long-term trends in bird numbers, total liveweight produced, number of houses, housing capacity, and number of growers on the Delmarva Peninsula, shown as 1-, 10-, and 20-year changes. Data illustrate consolidation of production into fewer, higher-capacity operations with increased total output. Source: Delmarva Chicken Association, "Facts & Figures" (accessed at https://www.dcachicken.com/facts/facts-figures.cfm).

Infrastructure and management practices on newer farms differ substantially from older facilities in ways that directly influence nutrient and ammonia dynamics. Newer complexes typically incorporate enclosed manure sheds, heavy-use area pads, and improved ventilation systems, including circulation or stir fans. These features reduce exposure of stored litter to precipitation, facilitate manure handling and export, and allow better control of in-house conditions. Data from late 2021 indicate that circulation/stir fans lower litter moisture and are associated with reduced in-house ammonia concentrations and lower peak levels prior to tunnel ventilation, demonstrating a practical means of limiting ammonia volatilization at the house scale. All poultry farms operate under nutrient management plans, which govern litter handling and application and are central to managing nitrogen flows from poultry operations to surrounding cropland and waterways.

Vegetative and structural practices further mediate air and water quality impacts from poultry production. Vegetative environmental buffers established around poultry houses have been shown to reduce dust by 49% and ammonia by 46%, while also providing visual screening and influencing local airflow patterns downwind of exhaust fans (Malone et al. 2006). At the field scale, grass filter strips substantially reduce sediment and fecal bacteria transported in runoff from manured fields: sediment concentrations were reduced by an average of 96% in 4.5-m strips and 98% in 9.0-m strips; average fecal coliform trapping efficiencies were 75% and 91%, respectively; and fecal streptococci trapping efficiencies were 68% and 74% for the same strip widths (Coyne et al. 1998). Together, these results indicate that both house-level and edge-of-field vegetative practices can materially reduce particulate, nutrient, and microbial exports, contributing to improved air quality and more sustainable nutrient management in poultry-dominated landscapes.

- "*Poultry Ammonia Emissions Production Trends*" – linked slides
  Dr. Rich Gates – Professor, Departments of Agricultural and Biological Engineering, and Animal Science; Director of the Egg Industry Center, Iowa State University

Ammonia emissions from poultry systems were described in terms of both daily emission factors and the methods needed to measure them accurately. Reported daily emission factors for broilers range from 0 to 2.34 g NH_3 $bird^{-1}$ d^{-1}, with variation linked to bird inventory, live animal weight, flock age, airflow, litter characteristics (moisture, pH, nitrogen content), and environmental conditions such as ambient and exhaust temperature and relative humidity (Topper et al. 2008). EPA's current work on emissions estimating methodologies for broiler operations similarly identifies inventory, bird weight, ambient temperature, and ambient relative humidity as key variables (EPA 2021). Emissions measurement was framed around combining ventilation rate and concentration in the exhaust stream(s), with a focus on calibrated fan performance and consistency in measurement frequency so values can be combined into hourly, daily, and longer intervals. Example estimates illustrated how daily emission factors can be used to estimate annual emissions for a broiler house under different assumptions about production cycle length, downtime, and bird inventory, and how these assumptions influence NH_3 inventory calculations. General trends in the poultry industry were outlined to show how production and management changes affect ammonia emissions. Feed conversion continues to improve as balanced rations reduce excess protein (nitrogen) in the feces, and phytase is used to reduce excess phosphorus. Broiler production relies on litter amendments for NH_3 control, and the layer industry is moving to cage-free systems, with manure belts that promote feces drying and reduce conversion of uric acid to NH_3; no new high-rise housing has been built for about a decade, and NH_3 emissions have been reduced in the past decade from these facility and management efforts. The Intelligent Portable Monitoring Unit (IPMU), which integrates sensors for NH_3, particulate matter, CO_2, air temperature, and fan/ventilation data with a microcontroller and an online control dashboard, was presented as a tool to provide more accurate and cost-effective emissions measurements (Dotto 2023). Case studies and example estimates from multiple U.S. regions and other countries highlighted the need for updated emission factors and improved measurement practices to better estimate and manage ammonia emissions from poultry operations.

- "*The Role of Litter Amendment Use in the Delmarva Broiler Industry"* – linked slides
  Dr. Casey Ritz, University of Georgia

Ammonia emissions in the Delmarva broiler industry were examined in the context of built-up poultry litter, in-house emission impact factors, and downwind concentration measurements. In-house factors affecting emissions included age of litter, litter moisture, temperature, relative humidity, bird density, market age, diet manipulation, health status, use of amendments, and litter management and movement. External influences such as seasonality, geographical location, ambient temperature, weather patterns, and atmospheric stability were also identified as important. Methods used to measure downwind ammonia concentrations included gas washing, electrochemical sensors, and photoacoustic spectroscopy, combined with dispersion analysis using Gaussian and Lagrangian models. A University of Georgia study measured path-average NH_3 concentrations at 100, 200, 300, and 500 ft downwind of broiler houses under defined "worst-case" operating conditions, with concurrent meteorological, climatological, and management data collection (Fairchild et al. 2009). Daily average NH_3 concentrations were found to decrease rapidly with distance under unstable (daytime) conditions and only minimally under stable (nighttime) conditions, with the climatic dispersion effect (variance divided by mean concentration) increasing much more rapidly during unstable periods and having minimal effect during stable periods, seen in Figure 9.

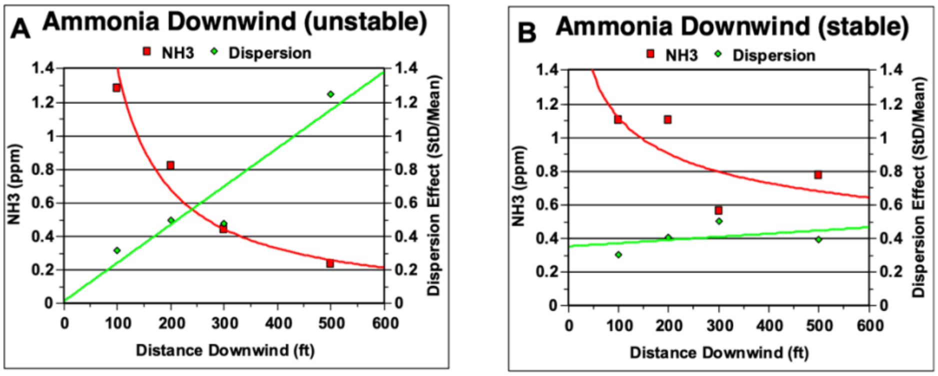

Figure 9. Downwind NH_3 concentrations (broiler production). Daily average NH_3 concentrations under unstable (daytime) conditions (left) and stable (nighttime) conditions (right). Under unstable conditions, NH_3 concentrations decrease rapidly with downwind distance following a power-function relationship, and the climatic dispersion effect increases sharply. Under stable conditions, NH_3 concentrations decrease only minimally with distance, and the climatic dispersion effect shows little change. Climatic dispersion effect is defined as the variance of the daily NH_3 concentration divided by the daily mean concentration. Figure adapted from materials presented in the STAC workshop (STAC 2022; https://www.chesapeake.org/stac/wp-content/uploads/2022/05/SPAC-Presentation-2022-print.pdf).

Ammonia emissions from broiler production were further compared across geographical regions and litter types, showing lower annual NH_3 emissions for operations using new litter in Europe and western U.S. sites and higher emissions for built-up litter systems in several U.S. regions, seen in Figure 10 (Harper et al. 2021). These comparisons were used to frame questions about causes of regional differences, reasons for disagreement among simultaneous measurements, the most appropriate techniques for evaluating trace-gas emissions, and the effects of climatic conditions on downwind concentrations.

Study	Location	Litter Conditions	Ammonia Emissions (kg NH_3 bird^{-1} year^{-1})
Germany	Europe	New litter[1]	0.016
United Kingdom	Europe	New litter[1]	0.040
California	Western U.S.	New litter[2,3]	0.099
Pennsylvania	Eastern U.S.	Built-up[1,4] (two to four flocks)	0.150
Texas	Southern U.S.	Built-up[1,4] (new litter to one flock)	0.180
Kentucky	Middle U.S.	Built-up[1,4] (two flocks)	0.230
Arkansas	Southern U.S.	Built-up[1,4] (one to two flocks)	0.250

Figure 10. Comparison of annual NH_3 emissions between geographical areas and litter types. [1]Wood shavings. [2]New litter on brood end (one-half of house) area and 7 cm new litter on top of remaining litter. [3]Rice hulls. [4]These emissions include the flock-period plus the period of clean-out, stockpiling of removed litter, removal of litter, and the empty down-time between flocks. Figure adapted from Harper, L.A., C.W. Ritz, and T.K. Flesch, 2021,

Ammonia emissions and dispersion from broiler production, Journal of Environmental Quality, 50:558–566, https://doi.org/10.1002/jeq2.20227.

- "*The Role of Litter Amendment Use in the Delmarva Broiler Industry*" – linked slides
  Dr. Jennifer Timmons – Associate Professor Poultry Extension Specialist,
  Department of Agriculture, Food and Resources Sciences,
  University of Maryland Eastern Shore

Litter amendment use in the Delmarva broiler industry was described with a primary objective of reducing ammonia volatilization from built-up litter, with additional benefits for bird health and house management. Commonly used products include sodium bisulfate (PLT®), aluminum sulfate (AL+ Clear®), acidified clay (Poultry Guard®), and citric acid for organic production. These amendments lower litter pH and temporarily bind or inhibit ammonia release (Gay and Knowlton 2005). Reported secondary benefits include reduced minimum ventilation rates, decreased fuel usage, improved on-farm food safety, enhanced flock health and welfare, and broader environmental benefits. On Delmarva, amendments were initially used mainly during winter months in the brood chamber but are now applied year-round throughout the entire house. The poultry company generally pays for the product, while growers pay for application.

Four main factors were identified as influencing ammonia volatilization from poultry litter: nitrogen level in the manure, moisture, heat, and pH. A study of multiple litter-amendment applications throughout a flock (Weiss et al. 2015) compared a single application at day 0 in the brood chamber (100 lb/1,000 ft^2) with a regimen adding applications on days 21 and 35 (50 lb/1,000 ft^2), and reported a 25.2 percent overall reduction in ammonia emissions over the 42-day grow-out period. Practical challenges to more frequent or expanded use include short layout times between flocks, product and application costs, and lack of equipment to support multiple in-flock applications. The presentation concluded that litter amendments are now widely adopted by growers as an ammonia-mitigation practice, are used year-round with adjustments to rates and timing, and that there remains potential to improve data quality and completeness on commercial management practices and amendment use to support ammonia emission mitigation.

- "*Commercial Poultry Production Management Research in the Bay Watershed*" – linked slides
  Dr. Jactone Arogo Ogejo – Associate Professor Extension Specialist,
  Department of Biological Systems Engineering, Virginia Polytechnic
  Mark Dubin, University of Maryland

A comprehensive review of commercial poultry production data research across the Chesapeake Bay watershed highlighted ongoing efforts to improve nutrient-generation estimates from poultry litter. Work conducted through the Poultry Litter Subcommittee (PLS), Agricultural Modeling Subcommittee (AMS), and university-agency research partnerships has focused on refining nitrogen (N) and phosphorus (P) estimates by compiling and analyzing extensive datasets from broilers, turkeys, and layers. These initiatives address key gaps in existing modeling approaches, particularly the Phase 6 Watershed Model, by replacing outdated American Society of Agricultural Engineers (ASABE) standards with updated methodologies derived from more than a decade of litter sample data, nutrient management plans, permit records, and commercial population datasets. Additional projects, including dedicated turkey and layer studies, have demonstrated where U.S. Department of Agriculture-National Agricultural Statistics Service (USDA-NASS) population data underrepresent localized commercial production, emphasizing the need to incorporate verified commercial data into watershed modeling inputs.

The Virginia Tech Chesapeake Bay Commercial Poultry Production Research Project, initiated in 2019, expands these efforts through direct collaboration with integrator companies and growers in Virginia and West Virginia to assemble detailed production and litter-management information. The project places strong emphasis on biosecurity, data privacy, and scientific validation, integrating company production records, grower surveys, state nutrient management databases, and new litter sampling. These combined datasets support county-level estimates of poultry populations, litter nutrient content, crust-out and whole-house cleanouts, use of litter amendments, and other management practices. The resulting information is intended to strengthen nutrient management planning, update assumptions within Bay modeling tools, and support the development and refinement of best management practices by contributing to improved environmental stewardship and agricultural sustainability across the region.

4.2 Summary of Mentimeter Results

The Mentimeter feedback collected during the STAC Ammonia Workshop identified several perceived obstacles to developing and integrating new poultry production management and mitigation data. Participants pointed to the high cost and time required for additional research, the tendency for modeling and data collection efforts to occur in isolated "silos," and the lack of sustained funding for survey-based data collection. Respondents also emphasized the need to document voluntary actions by farmers and to conduct operational-scale testing to demonstrate the economic, agronomic, and environmental performance of mitigation strategies. Disease outbreaks, both hard and soft costs of participation, and the willingness of poultry companies and growers to engage in surveys and data-sharing were noted as additional constraints.

Feedback also highlighted critical knowledge gaps in the representation of commercial poultry production management and ammonia mitigation. Participants underscored the importance of locally collected data, improved characterization of key production variables, and better quantification of ammonia release from poultry houses. They called for more information on broiler production efficiency, litter amendment use, and the fate of ammonia retained in litter after cleanout. The need for affordable best management practices (BMPs) with a clear return on investment, as well as a better understanding of how house location and site characteristics influence management decisions, was also noted. Repetition of studies at regular intervals was viewed as essential to maintain current, representative datasets.

To address these obstacles, participants suggested recognizing and using third-party information sources that can protect confidentiality, and explicitly addressing the spatial disconnect between national- or basin-scale total maximum daily loads (TMDLs) and local land management decisions. Recommendations included funding surveys that capture voluntary efforts, establishing a public repository for data and modeling tools, and identifying new funding sources for research, implementation, and application of mitigation practices. Overall, there was strong support for investing financial and technical resources in commercial poultry production management and ammonia mitigation data, emphasizing collaborative approaches and the need for accurate models to evaluate interventions and quantify their effects on ammonia emissions. Appendix I provides the full set of unedited Mentimeter responses, including participant input to all six workshop questions on obstacles, critical knowledge gaps, partnership roles, investment needs, and implications for modeling.

4.3 Conclusions

The presentations at the workshop underscore the evolving landscape of commercial poultry production, particularly in the Delmarva region and the broader Chesapeake Bay watershed and beyond. Experts highlighted significant advancements in production efficiency, housing technology, and environmental management practices, including the widespread use of litter amendments and emission control technologies. Presenters suggested these improvements are critical for enhancing flock health, reducing ammonia emissions, and promoting sustainable agricultural practices. However, challenges such as high research costs, limited equipment, and the need for consistent data collection remain barriers to broader adoption and implementation.

A recurring theme across all presentations and workshop feedback is the importance of accurate, and localized data to inform decision making regarding management efforts. Reliable data enables better modeling, supports nutrient management planning, and helps quantify the effectiveness of management efforts. It also provides opportunities to ensure that voluntary efforts by growers are recognized and that interventions are economically and environmentally sound. Continued investment in data collection, collaborative research, and transparent reporting is essential for advancing sustainable poultry production and protecting environmental quality in sensitive regions like the Chesapeake Bay.

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Appendix A: List of Tables

Appendix B: List of Figures

Figure 8. Long-term trends in bird numbers, total liveweight produced, number of houses, housing capacity, and number of growers on the Delmarva Peninsula, shown as 1-, 10-, and 20-year changes. Data illustrate consolidation of production into fewer, higher-capacity operations with increased total output. Source: Delmarva Chicken Association, "Facts & Figures" (accessed at https://www.dcachicken.com/facts/facts-figures.cfm).26

Figure 9. Downwind NH_3 concentrations (broiler production). Daily average NH_3 concentrations under unstable (daytime) conditions (left) and stable (nighttime) conditions (right). Under unstable conditions, NH_3 concentrations decrease rapidly with downwind distance following a power-function relationship, and the climatic dispersion effect increases sharply. Under stable conditions, NH_3 concentrations decrease only minimally with distance, and the climatic dispersion effect shows little change. Climatic dispersion effect is defined as the variance of the daily NH_3 concentration divided by the daily mean concentration. Figure adapted from materials presented in the STAC workshop (STAC 2022; https://www.chesapeake.org/stac/wp-content/uploads/2022/05/SPAC-Presentation-2022-print.pdf).28

Figure 10. Comparison of annual NH_3 emissions between geographical areas and litter types. [1]Wood shavings. [2]New litter on brood end (one-half of house) area and 7 cm new litter on top of remaining litter. [3]Rice hulls. [4]These emissions include the flock-period plus the period of clean-out, stockpiling of removed litter, removal of litter, and the empty down-time between flocks. Figure adapted from Harper, L.A., C.W. Ritz, and T.K. Flesch, 2021, Ammonia emissions and dispersion from broiler production, Journal of Environmental Quality, 50:558–566, https://doi.org/10.1002/jeq2.20227.28

Appendix C: Workshop Agendas

This workshop series on improving modeling and mitigation strategies for poultry ammonia emissions across the Chesapeake Bay watershed convened virtually over six sessions. The final session was held on Wednesday, June 1st, and focused on recapping the previous mini-workshops and discussing next steps. Agendas for each session are provided in this appendix.

Previous workshop sessions in the series included:

- **November 19, 2021** – Introduction: What are the key decision points related to this issue? Is the partnership supporting these decision points? How might they?
- **March 31, 2022** – Summarize the effectiveness of various best management practices (BMPs) and incorporate stakeholder input on the practical implications of these BMPs.
- **April 20, 2022** – Community Multiscale Air Quality (CMAQ) apportionment deep dive: How can these new results inform our Bay modeling and Bay restoration efforts?
- **April 21, 2022** – Follow-up session on the outputs from March 31. Define priorities, considerations, and options available for decision-makers.
- **May 4, 2022** – Examine critical knowledge gaps and obstacles to developing and integrating new poultry production management and mitigation data.
- **June 1, 2022** – Final session: Recap of previous mini-workshops and discussion of the process moving forward.

Scientific and Technical Advisory Committee (STAC)
Workshop:
Improving Modeling and Mitigation Strategies for
Poultry Ammonia across the Chesapeake Bay Watershed

9:00 **Welcome**
Kathy Boomer, Foundation for Food and Agricultural Research, STAC Chair

9:05 **Workshop Introduction**
Joe Wood, Chesapeake Bay Foundation
Holly Porter, Delmarva Chicken Association

9:20 **Presentation Question Task (10 minutes total)**
Mike Foreman, University of Virginia
Annabelle Harvey, Chesapeake Research Consortium, STAC Coordinator

JamBoard Test Question: What has been your "go to" restorative activity during the pandemic?

Session 1: Approaches to Modeling Ammonia Emissions and Transport

9:30 **Apportionment of air sources through CMAQ**
Jesse Bash, EPA

- What additional questions need to be addressed about this approach?
- What future analyses would be most beneficial?

9:50 **A conceptual model of how air sources fit into Chesapeake Bay Modeling,** *Gary Shenk, USGS*

- What are the challenges with the current framework?
- How might the partnership look to modify?

10:10 **Local Surveys and improving understanding of implementation**
Mark Dubin, University of Maryland
Paul Bredwell, U.S. Poultry and Egg Association

- How can litter surveys improve our understanding? What other ways might we improve our understanding of management efforts?
- How could these inputs inform our modeling efforts?

10:30 **Debrief the Modeling Questions**
Mike Foreman, University of Virginia

10:35 5-minute Break

Session 2: Approaches to Ammonia Management

10:40 **What management strategies influence ammonia transport? What is the relative cost effectiveness? co-benefits?**

Hong Li, University of Delaware
Sanjay Shah, North Carolina State University
Eileen Fabian, Penn State University

- What are key challenges related to implementing these BMPs and how might the partnership address these challenges??
- Are there other co-benefits we are not considering?
- What critical research questions remain?

11:40 **Debrief the management approaches**
Mike Foreman, University of Virginia

11:45 **Schedule of future breakout meetings, Future opportunities for participation**
Joe Wood, Chesapeake Bay Foundation

- What important questions in this space have we not covered; Do you have suggestions for new groups/ focused discussion?
- Do you have suggested resources we should review?

Future meetings will take a deep dive into these issues, including but not limited to the following.

- What are the key decisions points related to this issue? Is the partnership supporting these decision points? How might they?
- Historic Cost-Share Investments. What informed current decisions making about investment? Are there opportunities to enhance investment?
- CMAQ apportionment deep dive: How can these new results inform out bay modeling/bay restorations efforts? What questions are there about the approach?
- How much ammonia reaches freshwater portions of the watershed? Any implications?
- Litter Surveys, what do they show, should the bay partnership support this tool, if so, How?
- What is the effectiveness of BMPs at mitigating ammonia? How have these historically been modeled? Cost-effectiveness of ammonia influencing BMPs? co-benefits? carbon, bird health, etc.

12:00 **Adjourn**

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop Series – March 31, 2022

Improving Modeling and Mitigation Strategies for Poultry Ammonia across the Chesapeake Bay Watershed

Virtual Meeting
Workshop webpage

Thursday, March 31st
Register in advance

****Exact Times Are Subject to Change****

2:00 pm **Welcome and Overview of Questions and Goals** — *Joe Wood (CBF)*
Where have we invested cost-share dollars? What BMPs help reduce ammonia and what other benefits do they provide? What are the obstacles to implementation?

2:10 pm **Breakout Groups**
Participants will split into two concurrent breakout groups to discuss management strategies that influence ammonia including waste amendments, feed amendments, in-house treatment, exhaust treatment, storage treatment, land application, and new innovative approaches

- **Breakout 1: Scientific Review of BMPs** — *Sanjay Shah (NCSU), Hong Li (UDel)*
  This group will focus on summarizing nutrient implications and co-benefits of best management practices (BMPs).
  - What is the effectiveness of these controls?
  - What co-benefits are provided?
  - Suggested References?
  - What are the Critical Knowledge Gaps?
- **Breakout 2: Stakeholder Inputs** — *Holly Porter (Delmarva Chicken Association), Kathy Boomer (FFAR)*
  This group will summarize stakeholder input on practical/operational implications of best management practices (BMPs).
  - What are the obstacles and which obstacles can be overcome?
  - Which partners do obstacles influence?
  - How could the partnership help address the obstacles? New Policies? Resources? Other support?

3:20 pm **Reconvene: Breakout Group Facilitator Report Back** — *Mike Foreman (IEN)*

3:35 pm **Group Discussion and Takeaways**

3:40 pm **Outcomes Summary and Next Steps**
- What are the most critical knowledge gaps?
- How can the partnership help overcome obstacles to implementation?

4:00 pm **Adjourn**

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop Series – April 20, 2022

Assessing Ammonia Deposition to the Chesapeake Bay

Virtual Meeting
Workshop webpage

Wednesday, April 20th
Register in advance

****Exact Times Are Subject to Change****

1:00 pm **Welcome and Overview of Questions and Goals** — *Joe Wood (CBF)*

1:10 pm **Atmospheric Deposition and Emission Contributions using EPA's Community Multiscale Air Quality (CMAQ) Model** — *Jesse Bash (EPA)*

1:40 pm **Discussion of Nitrogen Sources to the Chesapeake: The role of ammonia from poultry relative to other sources, and the potential for reduction** — *Gary Shenk (USGS)*

2:10 pm **Breakout Groups**
Participants will be randomly split into breakout groups. Each group will discuss the following topics:

- **Topic 1:** What questions or concerns do you have about this tool?
    - Do you have questions/concerns or have any problems related to this?
    - Are we missing something here?
- **Topic 2:** How can we use this tool?
    - What do we do with this information? Does this tool allow us to do something that we don't currently do?
    - How do we use it?

2:50 pm **Reconvene: Breakout Group Facilitator Report Back** — *Joe Wood (CBF)*

3:30 pm **Adjourn**

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop Series – April 21, 2022

Session 2: Improving Modeling and Mitigation Strategies for Poultry Ammonia Emissions Across the Chesapeake Bay Watershed

Virtual Meeting

Workshop webpage

Thursday, April 21st

Register in advance

****Exact Times Are Subject to Change****

2:00 pm **Welcome and Recap of March 31st Workshop Session** — *Joe Wood (CBF)*

2:10 pm **Group Discussion: Defining priorities and considerations**
Participants will help develop a list of priorities and considerations associated with managing ammonia: Producer/Industry Consideration? Environmental consideration?

2:25 pm **Group Discussion: What management options available and who are they available to?**
Participants will help develop a list of options / decisions points that are available for managing ammonia.

2:40 pm **Breakout Groups: Identifying the most pertinent knowledge gaps?**
Participants will be randomly split into breakout groups for 15-minutes. Groups will be asked to consider the most important knowledge gaps for informing management.

2:55 pm **Break**

3:00 pm **Group Brainstorming Session: How can the partnership help?** As a group, participants will discuss ideas for how the partnership can move forward.

3:30 pm **Outcomes Summary and Next Steps**

4:00 pm **Adjourn**

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop Series – May 4, 2022

Improving Modeling and Mitigation Strategies for Poultry Ammonia Emissions Across the Chesapeake Bay Watershed

Virtual Meeting

Workshop webpage

Wednesday, May 4th

Register in Advance

****Exact Times Are Subject to Change****

01:00 pm **Welcome and Overview of Questions and Goals** —

Joe Wood, Virginia Senior Scientist (Chesapeake Bay Foundation)

What sources and data collection methods are available for representing commercial poultry production management practices related to the generation and mitigation of poultry ammonia emissions? Should we invest additional financial resources to collect this data? What are the primary commercial best management practices (BMPs) which can assist in reducing ammonia emissions for which implementation data should be collected? How often should the data be collected, and what are the obstacles to implementation?

01:05 pm **Chesapeake Bay Program Ammonia Data 101** –

Gary Shenk (USGS – Chesapeake Bay Program Office)

What are the existing sources of poultry production ammonia emissions data which are utilized to represent ammonia emission mitigation and deposition in the Chesapeake Bay Watershed Model (CBWM) and Chesapeake Assessment Scenario Tool (CAST)?

01:15 pm **Commercial Poultry Production and Ammonia Data** –

Paul Bredwell, Executive Vice President Regulatory Programs (US Poultry & Egg Association)

A series of scientific presentations on alternative sources of commercial poultry production research data including indicators of management trends and associated ammonia emissions.

- What was the data collected?
- What were the method(s) used to collect data?
- What was the level of difficultly/challenges in collecting the data?
- What was the quality/completeness of the data collected?
- How does it inform our knowledge on ammonia emissions and mitigation?

- Dr. Jon Moyle – Poultry Extension Specialist, Lower Eastern Shore Research and Education Center (LESREC), University of Maryland "Delmarva Commercial Poultry Production Management Trends"

- Dr. Rich Gates – Professor Departments of Agricultural and Biological Engineering, and Animal Science; Director of the Egg Industry Center,

Iowa State University
"Poultry Ammonia Emissions Production Trends"

- Dr. Casey Ritz – Professor University of Georgia
  "Commercial Broiler Management and Ammonia Emissions"

- Dr. Jennifer Timmons – Associate Professor Poultry Extension Specialist, Department of Agriculture, Food and Resources Sciences, University of Maryland Eastern Shore
  "The Role of Litter Amendment Use in the Delmarva Broiler Industry"

- Mark Dubin, University of Maryland College Park
  "Commercial Poultry Production Management Research in the Bay Watershed"
  Co-presenter Dr. Jactone Arogo Ogejo – Associate Professor Extension Specialist, Department of Biological Systems Engineering, Virginia Polytechnic Institute

02:00 pm **5-minute Break**

02:05 pm **Commercial Poultry Production and Ammonia Emissions** (continued) –

02:30 pm **Speakers Science Panel Discussion – Audience Questions and Answers** –
Mike Foreman, STAC Workshop Moderator (IEN)

03:00 pm **Group Discussion and Takeaways** –
Mike Foreman, STAC Workshop Moderator (IEN)
Mentimeter interactive polling will be used to gather group feedback and takeaways.

- What are the most critical knowledge gaps concerning the representation of commercial poultry production management and ammonia mitigation?
- What obstacles exist to developing and integrating new poultry production management and mitigation data?
- How can the partnership help overcome obstacles to enhanced data development and implementation?
- Should the partnership invest financial and technical resources into the development of commercial poultry production management and ammonia mitigation data?
- How can this information inform our modeling efforts?

03:30 pm **Group Mentimeter Outcomes Summary, Take-aways, and Next Steps** –
Joe Wood, Virginia Senior Scientist (Chesapeake Bay Foundation)

04:00 pm **Adjourn**

Chesapeake Bay Program's (CBP)
Scientific and Technical Advisory Committee (STAC)
Workshop Series – June 1, 2022

Assessing Ammonia Deposition to the Chesapeake Bay

Virtual Meeting
Workshop webpage

Wednesday, June 1st
Register in advance

****Exact Times Are Subject to Change****

2:00 pm **Workshop Overview and Steps Moving Forward** — *Joe Wood (CBF)*
Joe Wood will review the current plans for the STAC workshop report. Workshop participants will be provided the opportunity to review the draft report before it is finalized.

2:30 pm **Summary of Previous Workshop Sessions**
Steering Committee members will summarize findings and recommendations resulting from prior workshop sessions followed by 15-minutes for Q&A.

- **What do our modeling tools tell us about the size of air sources?** — *Jesse Bash (EPA), Gary Shenk (USGS)*
- **What management actions influence ammonia?** — *Hong Li (UDel), Sanjay Shah (NCSU), Holly Porter (Delmarva Chicken Association), Kathy Boomer (FFAR)*
- **How can the partnership improve our understanding of current levels of implementation?** — *Mark Dubin (UMD), Paul Bredwell (US Poultry and Egg Association)*

4:00 pm **Adjourn**

Appendix D: Workshop Sessions and Presentations

Session 1 — November 19, 2021
Introduction: What are the key decision points related to this issue? Is the partnership supporting these decision points? How might they? *Link to session webpage*

- Delmarva's chicken community
  Joe Wood, Chesapeake Bay Foundation
  Holly Porter, Delmarva Chicken Association
- Poultry sources in Chesapeake Bay Program nitrogen modeling
  Gary Shenk, USGS
- Commercial poultry production data research
  Mark Dubin, University of Maryland
  Paul Bredwell, U.S. Poultry and Egg Association
- Poultry litter amendments
  Sanjay Shah, North Carolina State University
- Management strategies influence ammonia release for poultry farms
  Eileen Fabian, Penn State University

Session 2 — March 31, 2022
Summarize the effectiveness of various BMPs and incorporate stakeholder input on the practical implications of these BMPs. *Link to session webpage*

- Improving modeling and mitigation strategies for poultry ammonia across the Chesapeake Bay watershed
  Kathy Boomer, FFAR

Session 3 — April 20, 2022
CMAQ apportionment deep dive: How can these new results inform our Bay modeling/Bay restoration efforts? *Link to session webpage*

- Atmospheric deposition and emission contributions using EPA's Community Multiscale Air Quality (CMAQ) model
  Jesse Bash, EPA
- Poultry sources in Chesapeake Bay Program nitrogen modeling
  Gary Shenk, USGS

Session 4 — April 21, 2022
Follow-up session on the outputs from March 31—Define priorities, considerations, and options available for decision-makers. *Link to session webpage*

- Group discussion slides
  Meg Cole, CRC

Session 5 — May 4, 2022
Examine critical knowledge gaps and obstacles to developing and integrating new poultry production management and mitigation data. *Link to session webpage*

- Chesapeake Bay Program Ammonia Data 101
  Gary Shenk, USGS
- Delmarva Commercial Poultry Production Management Trends
  Jon Moyle, University of Maryland
- Poultry Ammonia Emissions Production Trends
  Rich Gates, Iowa State University
- Commercial Broiler Management and Ammonia Emissions
  Casey Ritz, University of Georgia
- The Role of Litter Amendment Use in the Delmarva Broiler Industry
  Jennifer Timmons, University of Maryland Eastern Shore
- Commercial Poultry Production and Ammonia Data
  Mark Dubin, University of Maryland College Park
  Jactone A. Ogejo, Virginia Tech

Session 6 — June 1, 2022
Synthesis Final Session. *Link to session webpage*

Appendix F: JamBoard Responses

The following notes are transcribed from Jamboard responses collected during workshop breakout discussions. Text has been lightly edited for clarity, spelling, punctuation, and expansion of abbreviations, but original meaning and participant wording have been preserved.

Session 1:
Modeling
What new opportunities does this data present for the partnership?

- If more data on waste management practices and resultant emission reductions were collected and incorporated into the model, the model could provide feedback on the benefits of these practices.
- From conversations with NASA and the deposition leads, ammonia (NH_3) emissions out of southeastern Pennsylvania appear to be much higher than from the Delmarva Peninsula. Is this modeled? Are these emissions being counted?
- Best management practice (BMP) opportunities in poultry houses with ammonia monitoring in and around the house.
- Greater opportunity for more accurate attribution.
- Given that NH_3 generally deposits very quickly, can management near the source be discussed as a way to manage nitrogen (N) load to the Bay instead of assuming longer transport distances?
- Litter applications are modeled as fertilizer, but the dynamics may differ from anhydrous or inorganic N.
- Litter and other manure applications are treated differently than fertilizer emissions. Nitrogen in these applications is assumed to be either total ammonia nitrogen (TAN) or organically bound N. Organically bound N must be mineralized to ammonium (NH_4), at which point it competes between soil nitrification and volatilization.
- The data are very useful as inputs to U.S. Department of Agriculture (USDA) models to simulate NH_3 emissions from agricultural fields influenced by different cropping activities (e.g., cover crops, tillage intensity, irrigation).
- Given Gary's presentation showing substantial reductions from using litter amendments, completing the data collection effort is important.
- Can this information help estimate how much N is delivered to smaller waterbodies as well?
- For the first time the Chesapeake Bay Program (CBP) will be able to quantify a comprehensive list of oxidized and reduced nitrogen emissions throughout the region and the transport and fate of those emissions.
- Has the issue with National Emissions Inventory (NEI) livestock waste NH_3 emissions in Somerset County, MD (2011: 2,678 tons; 2014: 1,636 tons; 2017: 3 tons) been addressed? The 2017 value appears erroneous.
- As presented, only ammonia management practices that are cost-shared are credited in the model. Most farmer actions are not cost-shared. What is the actual level of implementation?
- Broiler litter is dry. If measuring ammonia from dry sources is difficult, how accurate are emission measurements from poultry litter?

What additional questions need to be addressed about this approach?

- What does the spatial distribution of ammonia look like around a poultry house or storage facility?
- How do buffers around farms affect transport? Trees in Virginia were mentioned.
- Do Community Multiscale Air Quality (CMAQ) model estimates reflect current rates of ammonia-management practices (e.g., litter amendments)? Are currently adopted practices embedded in the baseline?
- Should the model account for BMPs that are voluntarily and routinely implemented by industry and not limited to government cost-shared practices?
- Limited data exist around poultry facilities, but data exist around dairy and swine operations showing a rapid decline in concentrations within ~10 miles. Reference: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010GL046146
- Atmospheric deposition to tall vegetation is generally higher (e.g., trees), which reduces transport distance. The magnitude of this effect on air quality is unknown but may be better characterized using recent high-resolution satellite data (e.g., https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020GL090579).
- Current practices appear embedded in current emission estimates based on available observations. New modeling tools can estimate the impacts of reductions/increases in emissions by area or sector (https://doi.org/10.5194/gmd-2020-361).
- Are additional animal data sources incorporated into CMAQ (similar to Chesapeake Bay Watershed Model corrections using USDA Agricultural Census / National Agricultural Statistics Service [NASS] data)?
- Issue reposted: Has the NEI livestock waste NH_3 error in Somerset County, MD (2011, 2014, 2017) been corrected?
- Although the model correlates well with nationwide wet NH_3 deposition observations, it may underpredict wet NH_3 deposition in the Southeast.
- Nutrient form (species) matters.

What future analyses would be most beneficial?

- The presentations covered large scale modeling (CMAQ) & poultry numbers. What about field level studies on NH_4 production & transport? What do these studies tell us about possible biases in CMAQ?
- Presentations covered regional CMAQ modeling and poultry numbers. What about field-level studies of NH_4 production and transport? Do these highlight possible CMAQ biases?
- Continual flux measurements (not always NH_3) are collected and used to refine algorithms. Publications describing these methods: https://doi.org/10.1016/j.scitotenv.2019.07.058 and https://doi.org/10.1016/j.scitotenv.2019.133975
- What portion of N deposition in the Chesapeake Bay is endemic vs. imported from the airshed? How much Bay-generated ammonia and NO_x is not deposited within the watershed?
- Improved estimates of how many growers use poultry litter treatment and at what rates. Industry and sales data may help.
- Does windrow composting increase air emissions? If so, is there an alternative to achieve benefits without increased NH_3?

- What is the effectiveness of vegetative environmental buffers (VEBs) at reducing volatilization and surface-water transport? Are there bioretention opportunities?
- How does N excretion per bird and feed efficiency differ between organic and conventional systems?
- Does VEB benefit differ on farms with vs. without stormwater management systems?
- How do CMAQ dry deposition velocities compare with measured values?
- Litter management may impact other factors (bird health, fuel use, carbon footprint). Need holistic evaluation.
- What rates of litter treatment are most growers using? If low/medium, could cost-share incentives increase adoption?
- Do in-house litter treatments reduce NH_3 emissions and improve nitrogen-use efficiency when litter is land-applied? If unknown, this is a key research need.

What are the challenges with the current framework?

- NH_x deposition appears relatively constant despite increased poultry production.
- Many estimates; limited data. More research or use of existing ambient air monitoring may help.
- It seems ammonia loads are not associated with sources in the model—is this correct?
- If N is retained in litter (reducing NH_3 emissions), does CAST still assume all retained N ultimately reaches the Bay?
- Reducing air deposition and retaining N in litter improves N:P ratios. Does the model account for this?
- Agricultural inputs to the model have high uncertainty.
- Models do not capture temporal variation in poultry management.
- Better data are needed on litter treatment use. Could USDA/NASS include questions? Could industry partner with land-grant universities (LGUs) on surveys?
- Missing components:
    - Comprehensive overview of BMP practices across the entire production cycle
    - Research-based assessments of modern BMP adoption
    - Integration of in-house volatilization models with environmental models to assess cumulative impacts
- Limited data for unreported and non–cost-shared BMPs.

What might the partnership look to modify?

- The model needs to account for voluntary BMP implementation on litter amendments.
- Collaboration with industry and LGU partners is needed to increase reliable data availability, while addressing producer privacy and proprietary concerns.
- How is commercial fertilizer use quantified in CAST?
- Fertilizer data come from the Association of American Plant Food Control Officials (AAPFCO), reported by State Chemists as tons of N and P. CAST redistributes these across counties based on crop fertility needs after accounting for manure nutrients.

How can litter surveys improve our understanding? What other ways might we improve our understanding of management efforts?

- Surveys should ask what portion of the house receives litter amendments (e.g., brood area only, whole house, mid-flock application), and application rate per 1,000 ft^2.
- Dubin et al. studies may help validate USDA data and fill gaps for BMPs not tracked by states.
- Can surveys solve underreporting of widely used amendments?
- If litter amendments are ubiquitous, can modeled N effects be incorporated as baseline rather than BMP-dependent?
- Need improved collaboration between farmers and environmental stakeholders to get data into models.
- How will survey results be incorporated into modeling?
- Surveys should determine whether litter replaces commercial fertilizer. Current fertilizer estimates rely on national consumption data, which may not reflect regional conditions.
- What efforts exist to validate survey data?

How could these inputs inform our modeling efforts?

- Differentiate between BMPs and standard practices.
- Efforts need to be transparent to consider side by side with the existing data sources.

Other Comments:

- Are there litter amendments that target absorption of water to reduce litter moisture?
- New bedding has many negatives for bird health and food safety: increased salmonella, increased necrotic enteritis, other reductions in gut health, decreased brooding temperatures, and reduced bird comfort during brooding. Several large integrators have forbidden clean-outs due to the negative impacts on bird health and food safety.
- There are more chickens in houses today than in the past—capacity per square footage has increased. Production days, bird ages, and layouts need to be represented in the models. This is broiler-chicken specific.
- Is cost-share necessary for best management practices (BMPs) that are already economically beneficial to producers in the short term (for example, economic benefits indicated for using new litter each flock)?
- Surface area is another driver of ammonia flux from litter along with temperature. Different types of mechanical handling of litter greatly influence ammonia emissions. The more the litter is overworked, the more ammonia is released. Windrowing increases ammonia flux multiple-fold.
- Organic diets require overfeeding of protein in order to meet amino acid requirements, so ammonia excretion is greatly increased.
- Additional topics for consideration: more information and research on feed efficiency and reductions in actual nitrogen leaving the bird over time; focus on reducing litter moisture even in old litter; good water systems; good ventilation; proper clean-outs.
- Some integrators prohibit cleaning out due to negative impacts of new litter on bird health and food safety.
- Cost sharing of litter amendments can assist growers in moving from “production-level” application (e.g., brooding only) to emission-control levels with higher rates and whole-house application.
- Sulfate-based litter amendments bind ammonia and convert it to ammonium sulfate, a stable solid fertilizer. Once that conversion is completed, even if litter pH increases, the

ammonia bound by the amendment is not released into the atmosphere but is retained as a solid fertilizer in the litter.

- How are these litter treatments managed in an average poultry house, and how does this compare to the research treatments discussed (timing, rate, method, mixing)?
- Cost–benefit analysis may have to be done with regions in mind; for instance, the price of new bedding may not be the same across the watershed.
- There is concern that the economic "benefits" mentioned for using new bedding might not hold if a more comprehensive survey were conducted. When clean-outs are needed now, it is still very difficult to find sufficient sources of new bedding. Even if it were a good idea, replacement bedding stocks would be insufficient.

Management Approaches

What are key challenges related to implementing these BMPs and how might the partnership address these challenges?

- If houses are cleaned out after every flock, ammonia emissions might be reduced, but what is the impact on acres needed for land application and on the fate of land-applied nitrogen (N) and phosphorus (P) versus N lost as ammonia? What is the net effect on N loads?
- How can integrators support growers to clean out more frequently and use new bedding?
- Citation for broiler ammonia emission data: Wheeler, E.F., K.D. Casey, R.S. Gates, H. Xin, J.L. Zajaczkowski, P.A. Topper, Y. Liang, and A.J. Pescatore. 2006. Ammonia emissions from twelve USA broiler chicken houses. *Transactions of the ASABE* 49(5):1495–1512.
- Management at the farm level is difficult to track.
- Can the fate of litter be tracked, including whether it is, or can be, used to replace synthetic fertilizer?
- Need to consider the full cycle. Where does the litter go after it is removed from the house? Land application can be good for soil health but may raise concerns for neighboring communities.
- If ammonia is locked up with acidifiers and similar amendments, there may still be risk of N loss; this is perceived as a challenge.
- What are the implications of moving to miscanthus for bedding? It is understood that it is changed out more often, etc.
- There is a need to expand availability of these practices for producer cost-share support.
- Many of these practices are in place for animal welfare, but they are not tracked in models for water-quality purposes.

Are there co-benefits we are not considering?

- Many of these practices are in place for animal health and welfare. Tracking them will depend on farmer participation in providing specific data and will require funding. The Delmarva Land and Litter Collaborative (DLLC) is exploring ways this data can be collected.
- Is there evidence that increased N content in litter leads to decreased commercial fertilizer application?
- What are the human health implications, if any?

- New bedding has many negatives for bird health and food safety: increased salmonella, increased necrotic enteritis, other reductions in gut health, decreased brooding temperatures, reduced bird comfort, etc. Several large integrators have forbidden clean-outs due to these negative impacts.
- Many of these practices are already implemented for bird health. It is important to consider the full cycle of the litter. Even if in-house ammonia is reduced, there are questions about how poultry houses and litter piles are perceived by surrounding communities.
- There are a number of comments for this section that were inadvertently placed in the modeling Jamboard.

What critical research questions remain?

- There are conflicting messages on the state of manure transport. Sometimes manure is described as valuable and in demand (for broilers—which raises the question of why government subsidies for manure transport exist). Other times, disposal of manure is described as logistically and financially challenging in the Chesapeake Bay watershed. Which is more accurate, and does it vary by region?
- The Delmarva Land and Litter Collaborative has been gathering information on these topics. Many of these efforts require farmer participation.

Next steps: What important questions in this space have we not covered; Do you have suggestions for new groups/focused discussion?

- There has been no discussion about gasification of broiler litter on a regional scale, for example at a rate of 26,000 tons of broiler litter per gasifier per year, consistent with NRCS Practice 735 and the Chesapeake Bay Program BMP called MTT4. This approach eliminates both storage and land application of this litter.
- Once amended litter is land-applied, what happens to the nitrogen?
- Can the Chesapeake Bay Program Partnership develop guidelines for testing and researching amendments (e.g., scale, timing, application rates) so that they can be credited appropriately in models?
- Why are states not reporting ammonia-emission BMPs if they are actually implementing them?

Appendix G: Best Management Practice Literature Review

This appendix presents a brief literature review prepared for Session 2 of the 2022 workshop on ammonia emissions in the Chesapeake Bay watershed. The references are organized by best management practice (BMP) category, litter and feed amendments, in-house and storage treatments, exhaust controls (biofilters/scrubbers), vegetated buffers, and innovative/emerging approaches, and summarize reported effectiveness, co-benefits, and practical considerations. The list is not exhaustive, and inclusion does not imply endorsement; it was compiled to support the breakout discussions by grounding questions about performance, obstacles to implementation, and key knowledge gaps.

The materials referenced here are accessible through the hyperlinks below.

Litter Amendments

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Akdeniz, Neslihan. "A Systematic Review of Biochar Use in Animal Waste Composting." *Waste Management* 88 (April 1, 2019): 291–300. https://doi.org/10.1016/j.wasman.2019.03.054.

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Chowdhury, Md Albarune, Andreas de Neergaard, and Lars Stoumann Jensen. "Potential of Aeration Flow Rate and Bio-Char Addition to Reduce Greenhouse Gas and Ammonia Emissions during Manure Composting." *Chemosphere* 97 (February 1, 2014): 16–25. https://doi.org/10.1016/j.chemosphere.2013.10.030.

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Appendix H: Collaborative Participant Notes (Session 4, April 21st Discussion Document)

This appendix contains the collaborative participant notes collected during the Session 4, April 21, 2022, workshop. As included below, the document has been lightly edited for clarity (e.g., formatting and minor wording), but otherwise reflects the original content.

Participants used a shared Google document to respond to discussion prompts, record observations, and annotate key points in real time. Comments reflect a mix of producer perspectives, technical considerations, scientific observations, and operational insights related to ammonia mitigation, management options, data gaps, and emerging technologies. Notes were captured in suggestion mode and represent unedited participant contributions.

These notes informed the thematic synthesis presented in the main report, but the views expressed are those of individual participants and do not necessarily represent consensus positions of the workshop steering committee.

Defining Priorities and Considerations

Producer operational efficiencies - what matters most?

- Bird health / animal welfare (maximize production and performance)
- Supporting growers ("growers are the priority")
- Managing disease
- Cost and cost-efficiency
- Electricity and other energy costs
- Meeting specific market demands (e.g., organic production)

Comments:

- It can be misleading to say decisions are purely "consumer-driven." Many growers are motivated by wanting clean air and water and by pride in stewardship
- Example raised: cage layer vs. cage-free
    - Cages can allow better manure management.
    - There is strong pressure to move to cage-free based on perceived welfare and consumer preference.
    - This creates trade-offs among welfare, environmental impacts, and economics.
    - One state was noted as a major egg-layer state, making these trade-offs particularly important.

Role of NGOs and consumer pressure

- Some NGO campaigns shape what becomes a "consumer concern."
- A relatively small percentage of consumers can drive major changes in production systems.
- Some NGO-driven changes help environmental outcomes; others may introduce operational or economic challenges.
- Net impact is mixed and context-dependent.

Other operational considerations

- Worker conditions were mentioned as an important factor intertwined with efficiency and welfare.

Environmental considerations

- Minimizing ammonia transport to waterways.
- Clarifying overall environmental goals:
    - Air quality and nitrogen deposition under the Clean Air Act.
    - Watershed Implementation Goals for the states.
- Concern: if goals, models, and data are not aligned, Bay Program modeling tools may misrepresent conditions (e.g., using CMAQ as a proxy without sufficient nuance).

Current tools and practices

- A comprehensive study was referenced showing that repeated applications of a litter amendment (e.g., PLT):
    - Can reduce ammonia, improve barn environment, and offset commercial fertilizer use.
    - Impacts animal welfare and worker environment.
- However, litter amendments are not always used throughout the entire flock cycle, limiting potential benefits.

Appendix I: Session 5, Mentimeter Responses

This appendix summarizes participant input collected during Session 5 through a live Mentimeter poll. Six questions were posed to attendees to gauge perspectives on data needs, obstacles, and opportunities related to commercial poultry production management and ammonia mitigation. Sixteen participants responded to each question. The figures below present the unedited Mentimeter outputs for the following prompts:

- What obstacles exist to developing and integrating new poultry production management and mitigation data?
- What are the most critical knowledge gaps concerning the representation of commercial poultry production management and ammonia mitigation?
- How can the partnership help overcome obstacles to enhanced data development and implementation?
- Should the partnership invest financial or technical resources in developing commercial poultry production management and ammonia mitigation data?
- How can this information inform our modeling efforts?

These visual summaries reflect participants' real-time perspectives and were used to support subsequent discussion during the session.

What obstacles exist to developing and integrating new poultry production management and mitigation data?

Mentimeter

- Disease outbreaks
- Why does the producer agree to the survey? and what if they say no?
- Follow model of turkey litter survey project (ie, public private collaboration)
- hard costs as well as soft costs (labor, resources - time is money too) when looking at additional litter amendments applications
- Finances associated with implementing higher technology mitigation practices. Cost share for the poultry producers.
- Whether poultry companies and growers are willing to participate and sharing the results and results?
- The partnership should invest in these surveys so they can give appropriate credit to the industry
- Accept data from Chesapeake Bay partners willing to participate. The entire value chain.
- We should have a public data and model repository.

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What are the most critical knowledge gaps concerning the representation of commercial poultry production management and ammonia mitigation?

Mentimeter

- Local data collection
- We have to get the best practices that are currently being used to be part of the modeling. Especially those with dual roles - ie Vegetative buffers - water quality and ammonia mitigation but only credit for water quality.
- post cleanout what is the fate of the ammonia 'captured' in litter? Land application, storage, handling
- There is a lot of information available for ammonia production in the house, but it is difficult to capture ammonia release from the house. Improved efficiency of broilers (feed efficiency); litter amendment use can you get this from the companies?
- application of amendments - best timing, rates, etc
- What is the maximum benefit of ammonia mitigation practices for poultry compared to other animals, such as dairy and swine?
- Is there a Q/A/QC Process?
- For use of LITTER AMENDMENT, what is the gaseous NH3 produced over the litter and then actual NH3 exhausted to the environment.
- These need to repeated with some regularity.

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What are the most critical knowledge gaps concerning the representation of commercial poultry production management and ammonia mitigation?

Mentimeter

A full accounting and understanding of the variables that are associated with poultry production, how the different production practices might affect ammonia generation and economical ways to mitigate ammonia.

gap in model versus measured emissions

Weekness in defining and monitoring gaseous NH3 EMISSION FROM CHICKEN HOUSE may be more closely defined by actually capturing NH3 over time, as exhausted air, with and without Litter Amendments, as well as, introduce new technology.

Who is going to pay for the BMPs?

Use of BMPs that is affortable and with appropriate ROI, like N-fertilizer capture.

How much of this data can be utilized due to privacy concerns?

Costs and benefits of litter management strategies; also different scrubber technologies, from highly lo engineered scrubbers to vegetative buffers and combinations; 2) attention to house location and how local env't can complicate mng't.

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How can the partnership help overcome obstacles to enhanced data development and implementation?

Mentimeter

Count third party information that protects confidentiality. For example, generated by TSP's or suppliers that will certify their data

Address the spatial disconnect between national-scale total maximum daily loads and localized land management decisions

The partnership should realize that you can't help if you don't have a good handle on what current practice is

The partnership should fund these surveys to help capture voluntary efforts in the model.

Allow more use of data beyond "publicly available"

The partnership should find a way to QA/QC these surveys to help utilize

We should have a public data and model repository.

Second the open-source, public data repo

Provide funds or find funding agencies who are willing to sponsor research, implementation, and application

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Should the partnership invest financial/technical resources into the development of commercial poultry production management & ammonia mitigation data

Mentimeter

- Yes.
- yes
- Yes
- Yes, but also encourage governmental agencies to help.
- Yes- but we need help from all parts of the partnership.
- Yes and accept in-kind and financial support from the full partnership.
- Yes, all presenters mentioned numerous variables and a lack of accurate models - this funding could help measure different interventions and quantify their mitigation of ammonia per unit of cost.
- Yes - need to build capacity on the ground for data collection and management
- Collaborative approaches are good. More research is needed on these efforts to understand the fate and management of ammonia.

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Should the partnership invest financial/technical resources into the development of commercial poultry production management & ammonia mitigation data

Mentimeter

- Use funding to Build out the publicly available Bay Program model
- CBP can fill in where there is a distrust in agencies. Outreach?
- Yes but keep in mind we are talking about a very small percentage of nitrogen to the bay and ammonia is an issue that the poultry industry will always be working on
- Yes, if Partnership re-funds the expert panel coordination so mitigation data can be used

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How can this information inform our modeling efforts?

Mentimeter

CBP has to be willing to accept the research data - that's often a long-term hurdle.

allow for other than "publicly available"

Open up a dialog with the Chesapeake Bay partnership decision makers to gain their commitment on prioritizing these type of collaborative efforts.

These surveys provide an opportunity to inform the model on current management practices- in a way that 'cost share data' cannot.

Investigate linkages between house operation and watershed models to address inconsistencies, identify uncertainties, and guide research priorities - to improve these management models.

How can we help data become creditable within the Bay Program

need to see what hoops the verification group will require

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