**9/28/12 Draft**

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: SAB Review of Emissions Estimating Methodologies for Broiler Animal Feeding Operations and for Lagoons and Basins at Swine and Dairy Animal Feeding Operations

Dear Administrator Jackson:

This Science Advisory Board (SAB) report responds to a request from EPA's Office of Air and Radiation (OAR) to review and provide advice on scientific issues associated with EPA's development of Emissions-Estimating Methodologies (EEMs) at two types of animal feeding operations (AFOs): EEMs for barns or buildings at confined broiler AFO facilities, and an EEM for open lagoons and basins at swine and dairy AFO facilities. EEMs are tools for estimating air pollutant emissions from industries where site-specific emissions data are not available.

EPA developed the EEMs for broiler confinement facilities and for open lagoons and basins at swine and dairy AFOs in order to address requirements of a voluntary air compliance consent agreement signed in 2005 between EPA and nearly 14,000 broiler, dairy, egg layer, and swine AFOs. The EEMs will be used by the AFO industry to estimate daily and annual emissions for use in determining their regulatory responsibilities under the Clean Air Act (CAA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA). The pollutants monitored under the agreement include: ammonia, hydrogen sulfide, particulate matter, and volatile organic compounds. As part of the agreement, EPA is charged with developing EEMs for broiler, dairy, egg layer, and swine AFO sectors. EPA developed the broiler and lagoon EEMs after reviewing data on emissions from two key sources: a) the National Air Emissions Monitoring Study (NAEMS), and b) data that EPA received in response to a Call for Information that EPA released seeking additional data on AFOs and emissions to ensure the agency is reviewing the broadest range of available scientific data. The NAEMS is a two-year study of emissions from AFOs that produce pigs, broiler chickens, eggs, and milk. The study was funded by the AFO industry as part of the 2005 voluntary air compliance agreement with EPA.

EPA's draft EEMs are described in two draft February 2012 documents: ''Development of Emissions-Estimating Methodologies for Broiler Animal Feeding Operations'' (Broiler Report), and ''Development of Emissions-Estimating Methodologies for Lagoons and Basins at Swine and Dairy Animal Feeding Operations'' (Lagoon Report). The documents describe the sites monitored and the data submitted to EPA, and provide a detailed discussion of the statistical methodology used to develop the draft EEMs that are to be applied to AFOs throughout the country. The statistical analyses evaluated process parameters to determine if they were predictor variables that EPA could use to develop the EEMs.

EPA's broiler EEMs were developed for ammonia, hydrogen sulfide, particulate matter, and volatile organic compounds using NAEMS emissions and process information collected from four houses on one broiler operation in California and from two broiler operations in Kentucky. EPA's swine and dairy lagoon EEMs for ammonia were developed by combining NAEMS emissions and process information collected from three dairies, three swine breeding and gestation farms, and three swine growing and finishing farms. EPA's statistical analyses resulted in the use of the following input parameters for developing EPA's broiler EEMs: bird inventory; ambient meteorological parameters (i.e., temperature, relative humidity, and barometric pressure), and confinement parameters (i.e., house temperature and relative humidity). EPA's statistical analyses resulted in the use of the following input parameters for developing EPA's swine and dairy lagoon EEM for ammonia: ambient temperature, relative humidity, solar radiation and wind speed.

The SAB finds that the three broiler facilities and nine swine and dairy facilities used to develop EEMs represent a very small fraction of the one-half million AFOs in the country. The EEMs developed from these limited data are intended to be applied to AFOs throughout the country. The methods used in developing the EEMs are not well suited for extrapolation to conditions beyond those represented in the data set and therefore the EEMs cannot be assumed to be accurate predictors of emissions from other farms in the U.S. SAB concludes that EPA should not apply the current versions of the statistical and modeling tools for estimating emissions beyond those covered in the data set. EPA should consider using data collected through mechanisms outside of the consent agreement, including data published in literature, to expand the data set. In addition, SAB does not support the combination of swine and dairy lagoon/basin datasets to develop swine and dairy ammonia and hydrogen sulfide EEMs and finds significant problems with EPA's approach of using static predictor variables as surrogates for data on dynamic lagoon/basin conditions. In addition, SAB finds that there are significant uncertainties associated with the broiler volatile organic compounds data used in EPA's analysis and concludes that these data are insufficient to support development of a broiler EEM for volatile organic compounds at this time.

The SAB also finds that the EPA's EEMs in both Reports are based on statistical analyses of datasets that resulted in development of a small number of input parameters and that use mathematical models on key variables (e.g., cubic model with bird weight) that cannot be extrapolated beyond the range of values in the data set. In their current form, these EEMs and statistical interpretations cannot be assumed to represent other farms in the U.S. The EEMs and associated Reports should be revised to improve the statistical analyses of the datasets and more appropriately reflect processes at AFO sectors.

SAB strongly recommends that EPA develop a process-based modeling approach to make predictions of air emissions on broiler confinement houses and swine and dairy lagoons/basins. A process-based model would quantify the flows of materials from one process on a farm to the next (e.g., flows from feed through the animal housing to manure storage to field application and crop production). Process-based models would require consideration of emissions from each component of the farm system based on the concentrations and amount of reactants that lead to the emission from that component. By representing chemical and physical processes and constraints in an EEM, the SAB concludes that process-based models are more likely than the current statistical models to be successful in representing a broad range of conditions. This recommendation is directly supportive of recommendations provided to EPA in the 2003 National Research Council report *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. In their most rigorous forms, EEMs are data intensive; however, process considerations can be incorporated into models at a variety of levels of complexity. EPA should consider developing EEMs at a variety of levels of complexity to provide options for producers with different levels of data availability. While the NAEMS does not provide sufficient data to implement a rigorous process-based modeling approach, it is sufficient to start the development of a full model. EPA should identify critical data gaps and begin the process of identifying key parameters to be included within the process-based models. EPA should also consider conducting a full mass balance analysis to help in the assessment of key parameters that would be used in a process-based modeling approach. Within the body of this report, SAB has identified several key factors and parameters that affect emissions that EPA should consider within process-based modeling approaches and recommends several alternative approaches for developing a draft process-based lagoon/basin EEM for ammonia emission. SAB also has several recommendations regarding EPA's handling of negative and zero values for both direct concentration measurement and calculated emission values.

The SAB appreciates the opportunity to provide EPA with advice on this important subject. We look forward to receiving the Agency's response and to providing future advice on this topic.

Enclosures

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AFOs | Animal Feeding Operations |
| AFO Panel | SAB Animal Feeding Operations Emissions Review Panel |
| bLS | Backward Lagrangian Stochastic Model |
| CAA | Clean Air Act |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| $CH_4$ | Methane |
| EEMs | Emissions-Estimating Methodologies |
| EPA | U.S. Environmental Protection Agency |
| EPCRA | Emergency Planning and Community Right-to-Know Act |
| ER | Emission Rate |
| $H_2S$ | Hydrogen Sulfide |
| MDL | Minimum Detection Level |
| NAEMS | National Air Emissions Monitoring Study |
| N | Nitrogen |
| $NH_3$ | Ammonia |
| $NH_4$ | Ammonium |
| OAR | Office of Air and Radiation |
| PM | Particulate Matter |
| QA/QC | Quality Assurance/Quality Control |
| RPM | Radial Plume Mapping |
| S | Sulfur |
| SAB | EPA Science Advisory Board |
| SPV | Static Predictor Variables |
| THM | Trihalomethanes |
| TSP | Total Suspended Particulates |
| VOCs | Volatile Organic Compounds |
| VR | Ventilation Rate |

# 1. EXECUTIVE SUMMARY

EPA's Office of Air and Radiation (OAR) requested the Science Advisory Board (SAB) to review two draft documents related to animal feeding operations (AFOs) emissions (''Development of Emissions-Estimating Methodologies for Broiler Animal Feeding Operations'' and ''Development of Emissions-Estimating Methodologies for Lagoons and Basins at Swine and Dairy Animal Feeding Operations''). In these documents, EPA described draft emissions-estimating methodologies (EEMs) for broiler animal feeding operations and for lagoons and basins at swine and dairy AFOs in order to address requirements of a voluntary air compliance consent agreement signed in 2005 between EPA and nearly 14,000 broiler, dairy, egg layer, and swine AFOs. EPA requested the SAB to provide advice on scientific issues associated with EPA's development of the EEMs. The SAB was asked to comment on various aspects of EPA's draft Reports, including EPA's overall approach for developing the EEMs, combination of Lagoon and Basin data, use of static predictor variables within the EEMs, specific approaches for development of the Ammonia (lagoon $NH_3$) and broiler volatile organic compounds (VOCs) EEMs, and handling negative and zero data results.

The SAB Animal Feeding Operations Air Emissions Review Panel (AFO Panel) reviewed the draft EPA documents, considered public comments that were received on the draft Reports, and held a public meeting on March 14, 15 and 16, 2012 to provide advice to EPA on the scientific adequacy, suitability and appropriateness of EPA's EEMs and draft Reports. At the March 2012 public meeting, the SAB Panel considered oral statements that were received from the public and raised several questions and requested additional data which EPA responded to in separate documents that EPA submitted to the Panel in July and August 2012. The SAB held a follow-up public teleconference call on August 13, 2012 to review EPA's responses and the additional data and consider whether EPA's supplemental responses changed any of the Panel's preliminary key issues and recommendations that were raised at the March 2012 SAB Panel meeting. The AFO Panel held a public teleconference on October 24, 2012, to discuss substantive comments from Panel members on the draft SAB report SAB Review of Emissions Estimating Methodologies for Broiler Animal Feeding Operations and for Lagoons and Basins at Swine and Dairy Animal Feeding Operations. The enclosed report provides the advice and recommendations of the SAB through the efforts of the SAB Animal Feeding Operations Emissions Review Panel.

In its review of the EEMs , the SAB finds that a small number of broiler, swine and dairy facilities were used to develop the EEMs, and the EEMs developed from this limited sample are intended to be applied to AFOs throughout the country. The methods used in developing the EEMs are not well suited for extrapolation to conditions beyond those represented in the data set and therefore the EEMs cannot be assumed to be accurate predictors of emissions from other farms in the U.S. SAB concludes that EPA should not apply the current versions of the models for estimating emissions beyond those covered in the data set.

As outlined in responses to specific charge questions below, the EPA should consider using data collected through mechanisms outside of the consent agreement, including data published in literature, to expand the data set . The SAB does not support the combination of swine and dairy datasets to develop the swine and dairy lagoon/basin ammonia and hydrogen sulfide EEM since the differences in nutrient concentration and manure composition between swine and dairy lagoons and dairy basins make it erroneous to combine the data from these sources. The SAB finds significant restrictions with EPA's approach of using static predictor variables as surrogates for data on dynamic lagoon/basin conditions because such an approach would obscure key emission processes and variable interactions and fail to account for regional and inter-species variability among the fundamental drivers of emission processes. In addition, SAB finds that there are significant uncertainties associated with the broiler VOCVOC data used in EPA's analysis, and concludes that these data are insufficient to support development of a broiler EEMs for VOCs at this time.

SAB strongly recommends that EPA develop a process-based modeling approach to make predictions of air emissions from broiler confinement houses and swine and dairy lagoons/basins. This recommendation is directly supportive of recommendations provided to EPA in the 2003 National Research Council report *Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs*. A process-based model would quantify the flows of materials from one process on a farm to the next (e.g., process flows from feed through the animal housing to manure storage to field application and crop production). Process-based models would require consideration of emissions from each component of the farm system based on the concentrations and amount of reactants that lead to the emissions from that component. By representing the chemical and physical processes and constraints in an EEM, the SAB concludes that process-based models are more likely than the current statistical models to be successful in representing a broad range of conditions. In their most rigorous forms, EEMs are data intensive, however, process considerations can be incorporated into models at a variety of levels of complexity. EPA should consider developing EEMs at a variety of levels of complexity to provide options for producers with different levels of data availability. While the NAEMS does not provide sufficient data to implement a rigorous process-based modeling approach, it is sufficient to start the development of a full model.

A more detailed description of the technical recommendations is included in this SAB Report, and the responses to specific charge questions are highlighted below.

**Charge Question 1: EPA'S Approach for Developing the EEMS**

*Please comment on the statistical approach used by the EPA for developing the draft EEMs for broiler confinement houses and swine and dairy lagoons/basins. In addition please comment on the approach for developing draft EEMs for egg-layers, swine and dairy confinement houses.*

EPA developed separate broiler confined source EEMs for $NH_3$, $PM_{10}$, $PM_{2.5}$, TSP, VOC and $H_2S$ using emissions and process information collected from one broiler operation in California and from two broiler operations in Kentucky. EPA developed a swine and dairy lagoon open source EEM for $NH_3$ using emissions and process information collected from three dairies, three breeding and gestation swine farms, and three swine growing and finishing farms. EPA used the Statistical Analysis Software (SAS) package to statistically evaluate process parameters to determine if the predictor variables could be used by the EPA to develop these EEMs. Based on the results of EPA's predictor analysis, broiler EEMs were developed using the following input parameters: bird inventory; ambient meteorological parameters (i.e., temperature, relative humidity, and barometric pressure), and confinement parameters (i.e., house temperature and relative humidity). EPA's swine and dairy lagoon $NH_3$ EEM was developed using the following input parameters: ambient temperature, relative humidity, solar radiation, and wind speed.

SAB has a number of suggestions for improving the statistical approach used by the EPA for developing the draft EEMs for broiler confinement houses and swine and dairy lagoons/basins. The EEMs developed from this limited data are intended to be applied to AFOs throughout the country. The SAB finds that the EPA's EEMs in both Reports are based on statistical analyses of datasets that resulted in development of a small number of input parameters and that use mathematical dependencies on key variables (e.g., cubic dependence on bird weight) that cannot be extrapolated beyond the range of values in the data set. The approach used in developing the EEMs are not well suited for extrapolation to conditions beyond those represented in the data set and therefore the EEMs cannot be assumed to be accurate predictors of emissions from other farms in the U.S.

SAB concludes that EPA should not apply the current versions of the statistical and modeling tools for estimating emissions beyond those covered in the data set. EPA should consider using data collected through mechanisms outside of the consent agreement, including data published in literature, raw data from key studies, and data that support key literature. Suggestions for literature that should be considered are included within the attached References. EPA should consider the effects of location (site or farm), house within location, and flocks within house in model inference and prediction. EPA's model uncertainty analysis should recognize the limitations in using a small number of locations. EPA should consider approaches in addition to the cross-validation method used to evaluate the model.

In addition, SAB is concerned that EPA's application of polynomial regression for nonlinear models (e.g., the use of cubic functions to represent nonlinear dependence in average mass of animals) leads to poor predictions near the extremes of the experimental conditions and when the models are extrapolated outside of the range encountered in the data set (as would be likely in application of the EEMs to AFOs nationwide). SAB suggests that EPA restrict the range of mass that should be reported if the cubic model is used. SAB also recommends that orthogonal polynomials should be used if a polynomial approach is taken. EPA should also provide more information on the merits of applying such regression analysis within this project.

SAB also strongly recommends that EPA should develop a process-based modeling approach to make predictions of air emissions on broiler confinement houses and swine and dairy lagoons/basins. A process-based model would quantify the flows of materials from one process on a farm to the next (e.g., flows from feed through the animal housing to manure storage to field application and crop production). Process-based models would require consideration of emissions from each component of the farm system based on the concentrations and amount of reactants that lead to the emission from that component. By representing the chemical and physical processes in an EEM, the SAB concludes that process--based models are more likely than the current statistical models to be successful in representing a broad range of conditions. In their most rigorous forms, EEMs are data intensive, however, process considerations can be incorporated into models at a variety of levels of complexity. EPA should consider developing EEMs at a variety of levels of complexity to provide options for producers with different levels of data availability. . A simple approach might use a small number of variables to place constraints on predicted emissions, such as limiting total predicted ammonia emissions based on the nitrogen available in feed. A more complex approach to the same emissions might attempt to perform a mass balance on nitrogen. EPA should also identify critical data gaps associated with development of such modeling approaches and begin the process for identifying which key parameters should be included within the process-based models. EPA should consider conducting a full mass balance analysis to help in the assessment of key parameters that would be used in a process-based modeling approach.

SAB has identified several key factors and parameters that EPA should consider within process-based modeling approaches. Key factors and parameters that impact broiler emissions may include animal activity (perhaps assessed through lighting program hours for light and dark periods), diets, feed rate and composition, water management, manure composition (moisture and nitrogen), feed composition including total nitrogen that result in releases of gaseous pollutants, total number of animals, and ventilation rate. Key factors and parameters that affect dairy and swine lagoon emissions may include sulfur, nitrogen and carbon content of feed, conversion of feed nutrients to animal product (milk and meat) as a percentage of excreted manure collected in liquid storage, milk production levels and composition for dairies, seasonality, and the sulfur, nitrogen and carbon content, surface area, depth, manure residence time, volume, temperature and pH of the lagoons. The National Air Emissions Monitoring Study (NAEMS) does not provide sufficient data to produce a full model incorporating all of these key factors and parameters but is sufficient to start the development of a suite of models of varying complexity. In particular, the NAEMS data set did not include sufficient information for the steps from feed development to manure collection. Also, the NAEMS swine and dairy lagoons/basins data are particularly limited regarding feed input data, nutrient and chemical loading inputs into lagoons, and the chemical and physical composition and pH of lagoons .

**Charge Question 2: Combination of Lagoon and Basin Data**

*Please comment on the agency's decision to combine the swine and dairy dataset to ensure that all seasonal meteorological conditions are represented. In addition, the agency also seeks the SAB's comments on whether the agency should combine lagoon and basin data.*

After conducting an initial analysis of the NAEMS data submitted for swine and dairy lagoons/basins, EPA began developing a draft EEM for $NH_3$. EPA's review of the literature indicated that lagoon/basin emissions were influenced by several factors, including lagoon/basin pH and temperature. To enable the dataset used to develop the draft EEM to represent all seasonal meteorological conditions for the entire two year monitoring period, EPA decided to combine the swine and dairy data to develop the draft $NH_3$ EEM, and is considering whether to combine the swine and dairy data to develop the draft hydrogen sulfide EEM.

SAB strongly recommends that EPA not combine the swine and dairy dataset. The differences in nutrient concentration and manure composition between swine and dairy lagoons and dairy basins make it erroneous to combine the data from these sources. Lagoons and basins are not the same and operate very differently; a lagoon is used to provide biological treatment and long term storage, and a basin is used for short term storage and may not provide biological treatment. Lagoon decomposition of manure is much greater than in a basin, since lagoons maintain bacterial populations to aid in the digestion of newly added manure while basins do not. In addition, characteristics of swine and dairy manure are significantly different. A combination of these two datasets would overlook the basic differences in microbial processes and waste characteristics and undermine the credibility of conclusions drawn from such analyses.

EPA justifies combining the swine and dairy data to ensure that multiple seasonal meteorological conditions are represented and a sufficiently large enough data set is available for analysis. Although this combination of data sets attempts to resolve problems associated with inadequate sample design by combining data from separate species, it should not be done.

Furthermore, it is not appropriate to combine the data within species if there is no predictor variables describing the chemical, physical, and biological characteristics of the lagoons included in the model. For example variations in the chemical composition of dairy lagoons across the country, driven by differences in manure handling systems lead to differences in the processes that control ammonia (or other compound) emissions. Separating the swine and dairy lagoon data while still using the predictor variables selected in the current EEMs (i.e. ambient temperature, relative humidity, solar radiation and wind speed) will only provide an estimate for the specific lagoons that that the models were based The EPA should identify key gaps in the lagoon and basin data and should consider using data collected through mechanisms outside of the consent agreement, including data published in literature, data that support key literature, and raw data from key studies, to address data gaps.

**Charge Question 3: Use of Static Predictor Variables**

*Please comment on the agency's decision to use static predictor variables as surrogates for data on lagoon/basin conditions. Given the uncertainties in that approach, does the SAB recommend that EPA consider specific alternative approaches for statistically analyzing the data that would allow for the site-specific lagoon liquid characteristics to be used as predictor variables?*

To maximize the number of $NH_3$ emissions measurements used to develop the draft EEM, EPA used static predictor variables as surrogates for data on lagoon/basin conditions (i.e., nitrogen content of lagoon liquid, lagoon pH, oxidation reduction potential and temperature). EPA used the static variables of animal type, total live mass of animal capacity on the farm, and the surface area of the lagoon to represent total nitrogen loading rate and the potential for release to the air. SAB finds significant problems with EPA's approach of using static predictor variables as surrogates for data on lagoon/basin conditions. Such an approach would obscure key emission processes and variable interactions and fail to account for regional and inter-species variability among the fundamental drivers of emission processes. It would be inappropriate to extrapolate this approach to operations not represented by the study locations.

Several of EPA's static predictor variables are also individually deficient. For example, basin surface area is generally highly variable at swine and dairy facilities, particularly in situations where basins have sloping sides, where small changes in surface water depth can translate into large changes in surface area. Also, animal numbers represent a fundamental variable that drives nitrogen loading and, subsequently, $NH_3$ emissions. In addition, the range of climatic, management, feeding, and animal-performance conditions represented by the livestock operations in the NAEMS study is too narrow to provide reliable emission estimates across the full range of conditions in which dairy and swine producers operate in the United States (e.g., moderate winters or extended, hot summers are not represented).

As discussed further under the response under Charge Question 1, SAB recommends that EPA develop a process-based approach that uses appropriate, physically-based, region- and species-specific variables . SAB also recommends that the functional relationships in any statistical model should be based on the key drivers of emission processes.

**Charge Question 4: Alternative Approaches for Developing the $NH_3$ EEM**

*Does the SAB recommend that EPA consider alternative approaches for developing the draft NH3 EEM that balances the competing needs for a large dataset (to reflect seasonal meteorological conditions) versus incorporating additional site-specific factors that directly affect lagoon emissions. If so, what specific alternative approaches would be appropriate to consider?*

EPA requested SAB advice on alternative approaches for developing an $NH_3$ EEM that would balance the competing needs for a large dataset (to reflect seasonal meteorological conditions) versus incorporating additional site-specific factors that directly affect lagoon emissions. SAB concludes that EPA should consider the following alternative approaches for developing a draft $NH_3$ EEM, since there are limited data and the EEM should be broadly applicable across the U.S. for determining emissions from lagoons:

- <u>Expand Data Completeness Methodology:</u> EPA's data completeness methodology assumes that a valid monitoring hour is one in which 75% of the data recorded during that hour were valid . EPA should expand its data completeness criteria in order to increase the amount of data available to develop an $NH_3$ EEM. SAB finds that EPA should include data with less than 75% completeness for any given hour, since there are already many gaps in the data used for the development of these EEMs. In addition, EPA should examine the 75% completeness criteria for daily averages (A valid monitoring day is one in which 75% of the hourly average data values used were valid). These data need to be examined to ensure that there are not blocks of missing hourly averages that could affect the overall daily averages. EPA should consider whether the missing hourly values are random or whether they occurred in some discernible pattern, and consider using methods to "gap fill" missing data.

- <u>Use bLS Data Instead of RPM Data or In Conjunction With RPM Data:</u> EPA's calculated daily lagoon emissions were developed based on measurements obtained using the "Radial Plume Mapping" (RPM) model rather than the "backward Lagrangian stochastic" (bLS) model. EPA should consider using the emissions estimated with the bLS method, since there is such a paucity of data in the current RPM dataset. Since the drivers of emissions (i.e., lagoon chemistry and biology) are changing slowly (more in terms of weeks or months, not minutes), it may be preferable to use daily average data values rather than hourly values. If daily values are used, the bLS dataset has 285 valid days as opposed to only 69 valid days using the RPM model. These daily averages could be used in conjunction with measured lagoon characteristics in order to have a more robust model. In addition, published validation studies indicate that the bLS model has performed very well for open area sources.

- <u>Revise Units for Emissions Estimates:</u> EPA's unit for emissions is kg/30-min. SAB finds that EEMs that use kg/ha or kg/live wt or some other denominator that captures the physical differences of the operations would more appropriately account for actual emissions that are released at dairy and swine facilities.

- Use Appropriate Predictor Variables to Estimate Emissions: EPA should apply both the environmental factors (manure temperature, air temperature, wind speed, and solar radiation) and predictor factors/variables that actually drive emissions. These variables include available lagoon chemistry data such as nitrogen content and pH of the lagoon, and the manure management system. The potential effects of surface crust on emissions should also be considered. EPA's predictor factors/variables should have realistic biological thresholds and boundaries to ensure that the methodology does not result in an estimated emission rate that is not feasible. SAB also recommends that EPA compare the results of the EEMs that it develops with emissions reported in the literature.

**Charge Questions 5 and 6: Approaches for Handling Negative and Zero Data**

*Please comment on the EPA's approach for handling negative or zero emission measurements. In the interest of maximizing the number of available data values for development of the draft H2S EEMs for swine and dairy lagoons/basins, does SAB recommend any alternative approaches for handling negative and zero data other than the approach used by the agency.*

Some NAEMS emissions measurements were reported as either negative or zero emissions values. EPA considered whether to include these negative and zero emissions values in the data used to develop the EEMs. EPA evaluated whether the negative or zero values represented variability in emissions measurements due to instrument/equipment performance and concluded that all negative values should not be considered in the development of the EEMs. EPA also reviewed the data to see if the data quality measures were properly performed according to the Quality Assurance Project Plan.

SAB has several recommendations regarding EPA's handling of negative and zero values for both direct concentration measurement and calculated emission values. In general, a zero or negative direct concentration measurement value can occur due to a true value that is at or below the Minimum Detection Level (MDL), instrument measurement error, a measurement value that is adjusted by the equipment calibration offset procedure, and instrument fluctuation due to influence by ambient conditions. Each of these cases is considered individually and recommendations are provided in the full report,; in some cases the SAB recommends that zero and negative direct concentration values be included in the development of EEMs.

Negative and zero calculated emission data should be generally included when calculating EEMs. If the measured concentration data are considered valid and included in the dataset, then the emission value calculated from that dataset should also be considered valid, whether it is negative, zero or positive. If the calculated value is negative, EPA should consult the raw data to assess whether the value was due to calculation, instrument results, ambient conditions, or some other effect.

Outliers (observations that appear to be different from the other observations in the sample set) should be first treated per the quality assurance/quality control process to determine (if possible) their origin and then included or not in EPA's analyses with a clear explanation and documentation for the decisions made.

**Charge Question 7: Broiler VOC EEM**

*Please comment on the approach EPA used to develop the draft broiler VOC EEM.*

EPA reviewed the VOC compounds data submitted for the California and Kentucky broiler sites. The two sites used different VOC measurement techniques. Based on analysis of the measurement and analytical techniques and the VOC data, EPA used only the VOC data from the Kentucky sites when developing the draft VOC EEM.

SAB finds that there are significant uncertainties associated with the broiler VOC data collected as part of the NAEMS study. SAB therefore concludes that the broiler VOC data cannot support the development of a broiler VOC EEM at this time. Although the NAEMS dataset is too limited to produce an EEM, there are valuable components of the VOC data that should be reported. SAB concludes that the KY1B VOC data may generally be valid and usable if EPA extensively and clearly documents the methods that were used to collect VOC data. EPA should also provide information on the total and speciated VOC concentrations at the sites where data were collected. SAB recommends that EPA investigate the factors that drive generation of VOC emissions from broiler facilities and develop a process-based modeling approach to estimate VOC emissions from these operations.

**General Comments on the Draft Broiler and Lagoon Reports**

In addition to evaluating the technical content of the reports, SAB considered whether the draft Broiler and Lagoon Reports were presented in a clear, comprehensive, and scientifically sound manner. SAB also identified suggestions for alternative analyses or presentation that should be conducted. Overall, the SAB finds that many areas of EPA's draft documents should be enhanced to strengthen the clarity and scientific basis of EPA's analyses. SAB finds that both Reports should be updated to describe the importance of retaining a long-term goal for producing process-based models and to indicate additional data received by the agency from the NAEMS science advisor since the time of their initial publication. The SAB also concludes that the Reports should more comprehensively describe data completeness, representativeness, and limitations, and whether there are sufficient data to begin a process-based modeling approach. Various suggestions are included for improving EPA's statistical approach. Furthermore, SAB recommends that the Reports more fully explain why any of the NAEMS data were excluded from EEM development. Since NAEMS data have significant limitations, the Reports should include an assessment that considers use of 'outside' data that was not collected as part of the NAEMS data collection effort.

# 2. INTRODUCTION

## A. Background

In 2011, EPA's Office of Air and Radiation (OAA) initiated the development of draft emissions-estimating methodologies (EEMs) for animal feeding operations (AFOs) at broiler confinement facilities and for open lagoons and basins at swine and dairy AFOs. EEMs are tools for estimating emissions from AFOs and are commonly used to estimate emissions from industries where site-specific emissions data are not available. EPA developed EEMs for confinement structures (e.g., barns or buildings at broiler facilities) and for open sources (manure lagoons and basins at swine and dairy facilities).

EPA developed the EEMs for broiler confinement facilities and for open lagoons and basins at swine and dairy AFOs in order to address requirements of a voluntary air compliance consent agreement signed in 2005 between EPA and nearly 14,000 broiler, dairy, egg layer, and swine animal feeding operations. The goals of the agreement are to reduce air pollution, monitor AFO emissions, promote a national consensus on methodologies for estimating emissions from AFOs, and ensure compliance with the requirements of the Clean Air Act (CAA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA). The EEMs will be used by the AFO industry to estimate daily and annual emissions for use in determining their responsibilities under these regulatory programs. The pollutants monitored under the agreement include: ammonia, hydrogen sulfide, particulate matter, and VOCs. As part of the agreement, EPA is charged with developing EEMs for broiler, dairy, egg layer, and swine AFO sectors.

At broiler confinement facilities, young chickens between 28 to 63+ days old are raised for meat. The most common type of housing for broilers is enclosed housing with a compacted soil floor covered with dry bedding such as sawdust, wood shavings, or chopped straw. Mechanical ventilation is typically provided using a negative-pressure system, with exhaust fans drawing air out of the house, and fresh air returning through ducts around the perimeter of the roof.

Swine AFOs involve the breeding and growth of pigs for meat. Dairy AFOs produce milk.. At many swine and dairy AFOs, manure handled as a slurry or liquid is stored in external earthen impoundments such as anaerobic lagoons. Lagoons are designed to hold the total volume of manure and process wastewater generated in addition to precipitation runoff. In the dairy industry, liquid-solid separation may be used to remove solids collected from run-off from drylots and/or flushed manure from freestall barns and milking centers. The liquid from solids separation is sent to an external storage pond or anaerobic lagoon that is usually constructed as an earthen basin.

EPA developed EEMs for broiler confinement facilities and for open lagoons and basins at swine and dairy AFOs after reviewing data on emissions from two key sources: a) the National Air Emissions Monitoring Study (NAEMS), and b) data that EPA received in response to a Call for Information that EPA released that sought additional data on AFOs and emissions to ensure the agency is reviewing the broadest range of available scientific data. The NAEMS was a two-year study of emissions from AFOs that raise pigs and broiler chickens, and from egg-laying operations and dairies. The study was funded by the AFO industry as part of the 2005 voluntary air compliance agreement with EPA.

EPA developed separate broiler confined source EEMs for $NH_3$, $PM_{10}$, $PM_{2.5}$, TSP, VOC and $H_2S$ using NAEMS emissions and process information collected from one broiler operation in California and from two broiler operations in Kentucky. EPA applied Statistical Analysis Software (SAS) to statistically evaluate process parameters to determine if they were predictor variables that EPA could use to develop the EEMs. Based on the results of EPA's predictor analysis, EPA's broiler EEMs were developed using the following input parameters: bird inventory; ambient meteorological parameters (i.e., temperature, relative humidity, and barometric pressure), and confinement parameters (i.e., house temperature and relative humidity).

EPA developed a swine and dairy lagoon open source EEM for $NH_3$ using NAEMS emissions and process information collected from three dairies, three breeding and gestation swine farms, and three swine growing and finishing farms. EPA applied SAS to statistically evaluate the process parameters and determine input parameters in a manner similar to that used to develop the broiler EEMs and developed its swine and dairy lagoon $NH_3$ EEM using the following input parameters: ambient temperature, relative humidity, solar radiation and wind speed.

EPA statistically evaluated the process parameters using a mean trend function that provided a point prediction of emissions under a given set of conditions. EPA chose a mean trend function to quantify the relationship between predictor variables and pollutant emissions by analyzing the emissions data . EPA's EEM development process also involved choosing a probability distribution and covariance function to quantify other contributions to variability in emissions.

B. SAB Review

During the summer of 2011, EPA requested the Science Advisory Board (SAB) to provide advice on scientific issues associated with EPA's development of the EEMs. In February 2012, EPA developed two draft documents (''Development of Emissions-Estimating Methodologies for Broiler Animal Feeding Operations'' and ''Development of Emissions-Estimating Methodologies for Lagoons and Basins at Swine and Dairy Animal Feeding Operations''). The documents provided to the SAB describe the sites monitored, the data submitted to EPA, and a detailed discussion of the statistical methodology used to develop the draft EEMs. EPA intends to use this same overall approach to develop draft EEMs for egg-layer AFO facilities and swine and dairy AFO confinement houses.

EPA asked SAB to provide advice on EPA's overall approach for developing the EEMs. EPA also requested advice on whether it should combine lagoon and basin data, whether it should use static or dynamic predictor variables for its model, and how to handle data that were reported as negative or zero results. In addition, EPA requested advice on alternative approaches for developing the $NH_3$ EEM for swine and dairy facilities and on whether it should develop an EEM for VOCs.

The SAB Animal Feeding Operations Air Emissions Review Panel (AFO Panel) reviewed the draft EPA documents, considered public comments that were received on the draft Reports, and held a public meeting on March 14, 15 and 16, 2012 to provide advice to EPA on the scientific adequacy, suitability and appropriateness of EPA's draft Reports. The AFO Panel considered oral statements that were received from the public during the public meeting and written public comments that were received on the draft EPA documents. At the March 2012 public meeting, the AFO Panel raised several questions and requested additional data which EPA responded to in separate documents submitted to the AFO

Panel in July and August 2012. The SAB held a follow-up public teleconference call on August 13, 2012 to review EPA's responses and the additional data and consider whether EPA's supplemental responses changed any of the AFO Panel's preliminary key issues and recommendations that were raised at the March 2012 AFO Panel meeting. The AFO Panel held a public teleconference on October 24, 2012, to discuss substantive comments from Panel members on the draft SAB report SAB Review of Emissions Estimating Methodologies for Broiler Animal Feeding Operations and for Lagoons and Basins at Swine and Dairy Animal Feeding Operations.

EPA plans to consider the enclosed SAB advice on the draft Broiler and Lagoons Reports and revise and finalize these two documents and adjust its approach for developing EEMs based on SAB's input. EPA plans to develop draft EEMs for egg-layers, swine and dairy confinement houses and other pollutants for swine and dairy lagoons/basins consistent with approaches that EPA will take when finalizing its Broiler and Lagoons Reports, and submit Reports for these draft EEMs to the SAB for advice.

The Executive Summary highlights the SAB's major findings and recommendations. The SAB's full responses to the charge questions are detailed in Section 3.

# 3. RESPONSES TO EPA'S CHARGE QUESTIONS

## 3.1 SPECIFIC CHARGE QUESTIONS

## 3.2.1. EPA'S APPROACH FOR DEVELOPING THE EEMS

*Question 1: Please comment on the statistical approach used by the EPA for developing the draft EEMs for broiler confinement houses and swine and dairy lagoons/basins. In addition please comment on the approach for developing draft EEMs for egg-layers, swine and dairy confinement houses.*

Background:

EPA developed separate broiler confined source EEMs for $NH_3$, $PM_{10}$, $PM_{2.5}$, TSP, VOC and $H_2S$ using emissions and process information collected from one broiler operation in California and from two broiler operations in Kentucky. EPA developed a swine and dairy lagoon open source EEM for $NH_3$ using emissions and process information collected from three dairies, three breeding and gestation swine farms, and three swine growing and finishing farms. EPA applied Statistical Analysis Software (SAS) to statistically evaluate process parameters to determine if they were predictor variables that EPA could use to develop these EEMs. Based on the results of EPA's predictor analysis, EPA's broiler EEMs were developed using the following input parameters: bird inventory; ambient meteorological parameters (i.e., temperature, relative humidity, and barometric pressure), and confinement parameters (i.e., house temperature and relative humidity). EPA's swine and dairy lagoon $NH_3$ EEM was developed using the following input parameters: ambient temperature, relative humidity, solar radiation and wind speed.

Overall Recommendation

In its review of the EEMs , the SAB finds that a small number of broiler, swine and dairy facilities were used to develop the EEMs, and the EEMs developed from this limited sample are intended to be applied to AFOs throughout the country. The methods used in developing the EEMs are not well suited for extrapolation to conditions beyond those represented in the data set and therefore the EEMs cannot be assumed to be accurate predictors of emissions from other farms in the U.S. SAB concludes that EPA should not apply the current versions of the models for estimating emissions beyond those covered in the data set.

Statistical Approach

SAB reviewed the statistical approach taken by EPA for estimation of air emissions from broiler confinement operations and dairy and swine lagoons. In addition, SAB will comment on the recommended approach for egg-layers, swine and dairy confinement housing.

A significant concern exists about the ability to use the EEM broiler and lagoon/basin models that were developed to extrapolate to other farms with reasonable accuracy. While the statistical approach to the analysis of the data may be acceptable for the small number of locations and limited range of conditions represented in the dataset, the EEMs are not well suited for extrapolation to conditions beyond those represented in the data set. Such extrapolations will be necessary if the EEMs are applied nationally. Further, some of the variables used for the model predictions do not make mechanistic sense. Using variables that are known to be logically or experimentally linked to the emissions (e.g., nitrogen content of litter to predict ammonia emissions) would seem more physically plausible and would be more credible and more likely to perform well across a broader collection of facilities.

To make accurate predictions across farms, measurements would be required on a larger number of farms. Only three sites were evaluated for poultry operations and they are unlikely to represent the industry as a whole. Only one site was used to estimate VOC emissions from poultry houses, and this was clearly not adequate to derive meaningful conclusions for the entire nationwide industry. In addition, only six swine and three dairy lagoons cannot represent all lagoons across both industries. Also, SAB cautions against the use of polynomial models when the use of the model is likely to extend beyond the range of data measured to develop the relationships since such models can lead to clearly erroneous predictions under certain production regimes employed in the U.S. (e.g., negative emissions or "near zero" emissions from large birds).

SAB finds that most emission measures were over-weighted for periods of higher emissions such as during warmer weather, and the range in weather parameters for the dataset may not reflect the range in measurements across the country. The AFO Panel recommends evaluating the effects of weather on emissions and evaluating the ranges in weather patterns within the dataset relative to the industry across the U.S. to determine how much of the data collected can be extrapolated to farms in different climatic regions. In general, ranges of data should be explained in the Reports and extrapolation beyond those limits should be counter indicated.

An alternative to the current approach is models that are more process-based, however, this will be challenging with the existing NAEMS data set.

<u>Process-based Models</u>

SAB strongly recommends that EPA develop process-based models of air emissions from AFOs of all types (e.g., broiler, dairy, egg layers, swine, etc.). This approach was recommended previously and described in detail by the National Research Council (2003). A process-based model would quantify the flows of materials from one process on a farm to the next (e.g., flows from feed through the animal housing to manure storage to field application and crop production). Rigorous process-based models would require consideration of emissions from each component of the farm system based on the concentrations and amount of reactants that lead to the emission from that component.

For example, emissions from manure lagoons would be based on composition of manure, which would in turn depend on flows into and out of the manure lagoon. The flows into the manure lagoon would be derived from the manure production from the animal housing in the form of excreted feces and urine and bedding. Flows into a lagoon would also need to consider the input from the milking parlor, and account for clean water collection from slabs and surfaces that may change the volume and solids ratio. The flows out of the lagoon would be equivalent to the flows into the field component as manure spread minus compounds emitted into the air or leached or mineralized through the soil. Furthermore, the flows in the manure lagoon would be quantified for each air species of interest (e.g., $NH_3$, $CH_4$) based on the nutrient loading rates and concentrations of the nutrients that lead to those species (e.g., urea, $NH_4$, organic N, organic carbon).

Process-based models could use additional data published in the literature, data that support key literature, raw data from key studies, or data separately collected by EPA or other entities. These data would need to measure the emissions from various components for the farm enterprise as a function of variables that should matter based on a mechanistic understanding of the emissions. For example, nutrients in animal manure could be estimated based on nutrient intake and production rates or at least expected intake for a level of production. Nitrogen flows would be especially relevant to ammonia emissions. The amount of urine and fecal nitrogen could be used to estimate emissions from the barn floor or subsequent manure storage and application. The NAEMS data could be used to some extent to evaluate accuracy of the process-based model.

Rigorous process-based models are data intensive, however, process concepts, such as limiting predicted releases of nitrogen in emissions to be less than nitrogen inputs, can be used in simplified models. Models of varying complexity should be developed (as EPA did with the proposed EEMs) based on the level of input provided by a given producer (e.g., one model may be developed considering the composition of a feed ration while a less complex model using default industry values could be used if a producer does not wish to or cannot disclose information regarding feed rations).

The advantages of using a process-based model include the following:

- More existing data could be used, such as data from estimated emissions for a certain component of the farm under certain conditions.

- Estimates derived would be more robust across different farm types.

- Control strategies could be developed for reducing emissions from farms based on implementing technology standards or performance standards, wherein the standards would predict specific impacts using the process-based models.

## 3.2.2. COMBINATION OF LAGOON AND BASIN DATA

*Question 2: Please comment on the agency's decision to combine the swine and dairy dataset to ensure that all seasonal meteorological conditions are represented. In addition, the agency also seeks the SAB's comments on whether the agency should combine lagoon and basin data.*

Background:

After conducting an initial analysis of the NAEMS data submitted for swine and dairy lagoons/basins, EPA began developing a draft EEM for $NH_3$. EPA's review of literature indicated that lagoon/basin emissions were influenced by several factors, including lagoon/basin temperature. To ensure that the dataset used to develop the draft EEM represented all seasonal meteorological conditions for the entire two year monitoring period, EPA decided to combine the swine and dairy data that EPA relied on to develop the draft $NH_3$ EEM.

Response:

SAB recommends that EPA not combine swine and dairy datasets. The EPA justifies combining the swine and dairy data to ensure that multiple seasonal meteorological conditions are represented and a sufficiently large data set is available for analysis. Initial site selection for dairy lagoons in this study did not provide representation for measurements of all seasonal meteorological conditions. Neither Moderate winters nor extended hot conditions in summer were represented. Although combining data sets attempts to resolve problems associated with inadequate sample design by combining data from separate species, it should not be done, and it is not clear what inferences could be made from any resulting models.
Lagoons and basins are not the same and operate very differently. Treatment lagoons rely upon microbial populations to digest organic fractions of manure. Intermediary compounds are consumed by other populations of microbes. The net result is digestion and decomposition of organic matter. This process occurs more rapidly in lagoons than in basins. Differences in chemical composition and concentration between swine and dairy lagoons make it difficult (if not erroneous) to combine the data from these two sources. Combining species data without correcting for nutrient loading rates and chemical differences overlooks the basic differences in microbial processes and waste characteristics and undermines the credibility of conclusions drawn from such analyses.

Although the current EEM approach represents multiple seasons, little attention is paid to information on chemical, physical, and biological differences in the contents and functionality of the various lagoons and basins; and difference in species, production efficiency, diets, feed intake, animal stocking density, injection of fresh water, lagoon loading and many other factors. Inputs into lagoons/basins (loading rates for nutrients and chemical constituents) vary by facility and must be considered as these are feedstocks for microbial populations present in containment structures. More rapidly fermentable carbohydrates will be present in the swine manure. Different compositions of nitrogen and sulfur are also expected. Combined, these differences in influent concentrations will translate to differences in microbial decomposition activities, rates, and intermediary compounds, all influencing potential conversion to methane or non-conversion and potential release of emissions to the atmosphere.
Nitrogen quantity and composition in waste streams, pH, temperature at the interface between the water

surface and the atmosphere, and wind speed are known to play key roles in volatilization of nitrogen as ammonia, yet none of these factors is considered in EPA's EEM.

It appears now, after the monitoring is done and the analysis is being undertaken by EPA to develop EEMs, flawed approaches are being used to try to cover for flaws in the study design. EPA reports that basin and lagoon data were combined to allow the estimation of basin $NH_3$ emissions in high temperature ranges only measured in lagoons. Extrapolating basin $NH_3$ emissions to higher temperatures based upon lagoon $NH_3$ emissions measured at higher temperatures is an example of such erroneous analytical practice. This extrapolation assumes that basin and lagoon $NH_3$ emission dependency on temperature is the same. Such an assumption is not known to be true. EPA should clarify what other contributing factors to $NH_3$ emissions are different between the lagoons and the basins that might affect $NH_3$ emissions. For example, clarify:

- Whether the basins developed any crusts or other solids on the surface which might obstruct diffusion of $NH_3$ across the liquid/atmosphere interface.
- Dimensions of the basins and lagoons.
- Whether there are significant differences between lagoons and basins that would affect the wind fetch and hence gas stripping effects of flow across the liquid/atmosphere interface.
- Whether there are pH differences.
- Whether redox potentials are similar.
- Whether any basins have anoxic surface layers.

The NRC (2003) report on AFO emissions concluded that emissions should be estimated based upon a process-based model (NRC, 2003). If different treatment systems are going to be combined, the process-based approach will be even more important. To do this, first the microbial processes must be shown to be sufficiently similar. Once this is established, then it might be possible for EPA to identify lagoon and basin differences in waste nitrogen, sulfur, carbon concentrations, residence time, temperature, pH and other characteristics, and identify the range of data needed to develop process-based emission models. This would require taking into account how the microbial processes and the chemical and physical processes are controlled by dominant characteristics in each system.

Developing a rigorous process-based EEM will require extensive data, beyond that available in the NAEMS data set. To address this data gap EPA should consider using data collected through mechanisms outside of the consent agreement, including data published in literature and data that support key literature.

## 3.2.3. USE OF STATIC PREDICTOR VARIABLES

*Question 3: Please comment on the agency's decision to use static predictor variables as surrogates for data on lagoon/basin conditions. Given the uncertainties in that approach, does the SAB recommend that EPA consider specific alternative approaches for statistically analyzing the data that would allow for the site-specific lagoon liquid characteristics to be used as predictor variables?*

Background:

To maximize the number of $NH_3$ emissions measurements used to develop the draft EEM, EPA used static predictor variables (SPVs) as surrogates for data on lagoon/basin conditions (i.e., nitrogen content of lagoon liquid, lagoon pH, oxidation reduction potential and temperature). EPA used the static variables of animal type, total live mass of animal capacity on the farm and the surface area of the lagoon to represent $NH_3$ precursor loading and the potential for release to the air.

Response:

SAB finds significant problems with EPA's approach of using static predictor variables as surrogates for data on lagoon/basin conditions. Such an approach would obscure key emissions processes and variable interactions and fail to account for regional and inter-species variability among the fundamental drivers of emission processes. It would be inappropriate to extrapolate this approach to types of operations not represented by the study locations.
The SAB recommends that the functional relationships in any EEM should be based on the key drivers of emission processes.

Use of static predictor variables as surrogates for data on lagoon/basin conditions

To develop an EEM for $NH_3$ emissions from lagoons and basins at dairy and swine operations, EPA proposes to use SPVs such as total animal live weight and lagoon surface area, derived by statistical regression techniques, in lieu of time-varying, lagoon- or basin-characterization data directly and fundamentally related to the respective emissions processes. Examples of the latter would include lagoon nitrogen loading, feed-to-gain performance (e. g., for feeder pigs), and milk production (for milking herds).

Simplified to its essence, EPA's modeling approach takes the form

$$E_i = \sum \{ \beta_{ij} * SPV_j \} + \beta_{i0} + \varepsilon_i$$

in which $E_i$ is the emission rate of compound i, $\beta_{ij}$'s are regression coefficients, $SPV_j$ is the jth SPV, $\beta_{i0}$ is the regression intercept for compound i, and $\varepsilon_i$ is the model's error term associated with compound i. In EPA's formulation, the SPVs may be either raw or transformed measurement data, depending on the individual variables' distributions.

As presented in the draft EPA report, the SPV approach is problematic for a number of interrelated reasons:

1. To the extent that a given SPV is not clearly, unambiguously, and fundamentally related to the emission rate through a well-established emissions mechanism – the resulting EEM cannot be reasonably extrapolated to other livestock operations. Given EPA's desire to use the EEM on facilities across the United States, the model should account for the wide variation in design, climate, and management factors across the United States.

2. Several of the SPVs that EPA selected for its EEM are individually deficient. For example:

   a. Basin surface area – in the case of basins that are managed as anaerobic lagoons and that therefore maintain a relatively constant depth of material over time, basin surface area would be a reasonable SPV. However, design and management factors – both of which are site-specific – determine whether or not a given basin actually maintains a constant depth. In the general case, particularly where basins have sloping sides, small changes in depth can translate into large changes in surface area, even within a span of hours to days.

   b. Animal numbers – it is reasonable to suppose that nitrogen loading to a basin scales by animal numbers provided that all other feed-intake, retention/milk production, and management variables remain static. But that (highly contingent) scalability ought not be taken to mean that animal numbers represent a fundamental variable driving $NH_3$ emissions. In the case of dairies, for example, milking herds may be managed according to productivity, feeding higher-energy, higher-protein diets to higher-producing cows, and vice-versa. Simply doubling herd size, without knowledge of the feed intake, performance, management factors associated with the additional animals, and the degree of solids separation does not necessarily double the emissions attributable to the per-animal emissions processes; but that is what the SPV approach implicitly assumes.

3. Dairies and swine operations differ substantially and in ways that cannot reasonably be collapsed into a single pseudo-species. Because nitrogen loading to a lagoon or basin – a key driver of $NH_3$ emissions – is driven in large measure by feed composition, feed intake, nitrogen retention (for swine operations), and milk production (for dairies), among other key variables, inter-species effects on diet and the manure produced must be taken into account in SPV evaluation. Swine and dairy EEMs should be individually formulated.

4. The range of climatic, management, feeding, and animal-performance conditions represented by the livestock operations in the NAEMS study is too narrow to provide reliable emissions estimates across the full range of conditions in which dairy and swine producers operate in the United States. For example, the data sets used in the NAEMS study do not represent moderate winters or extended, hot summers.

In summary, EPA has attempted to overcome serious deficiencies in the NAEMS data sets by appealing to a statistical analysis that obscures key emissions processes and variable interactions, that fails to account for regional and inter-species variability among the fundamental drivers of emission processes, and that cannot reasonably be extrapolated to types of operations not represented by the study locations. In lieu of EPA's approach to EEM development, the SAB recommends that EPA move in the direction of a more process-based approach that uses appropriate, physically-based, region- and species-specific variables.

Alternative approach for statistically analyzing the data

A statistical model developed from limited data will not provide a satisfactory EEM for use beyond the dataset from which it was created. An alternative to the statistical approach proposed by EPA is to develop a functional relationship based upon scientific understanding of the principles involved in the emission process and then use a statistical procedure to help quantify the required parameters. This must begin by identifying the appropriate dependent and independent variables. For ammonia emission from a manure lagoon or basin, for example, the predicted variable should be the emission per unit surface area of the lagoon or basin. The independent variables must include both weather conditions and manure characteristics. Important weather variables that must be included are ambient temperature and wind speed. Solar radiation and precipitation may also contribute and should be used if the data are available. Important manure characteristics include dry matter and nitrogen concentrations. The organic and inorganic nitrogen contents would also be helpful if that information is available. Other important manure characteristics include pH and temperature (if it is different from ambient temperature). Management can affect the amount of crusting that occurs on the manure surface, and a surface crust can reduce emissions from 20 to 80% depending upon the thickness and uniformity of the crust across the surface. If the appropriate manure characteristics are defined and used, the manure source (e.g., dairy, swine, and poultry) should not be important. For all of these variables, the temporal resolution of the data should be consistent with the time scales on which the variables are changing. For example, Manure characteristics will not change rapidly, so hourly or daily data are not needed for these variables. .

The functional form of the predictive relationship must be established based upon the biological, chemical and physical processes driving emissions. As the independent variables approach maximum and minimum potential values, predicted emissions must also approach appropriate values (i.e., emission predictions must approach zero under the appropriate conditions and approach some maximum value at the outer extremes). Unreasonable predictions such as negative or infinite values cannot occur. Most often this will require nonlinear relationships. The functional relationship must allow an appropriate prediction across the full possible range of each independent variable and combination of variables that might be used. Only this type of relationship can be used to extrapolate to conditions outside the original dataset. An EEM that is applied to all manure storages throughout the country must be satisfactorily applied to conditions beyond the limited data from which it was developed.

After the functional form of the relationship is established and the appropriate independent and dependent variables are included in that function, a statistical approach can be used to help quantify parameters along with scientific understanding. Somewhat limited data can be used to determine parameters that should be appropriate beyond the bounds of the original data. Extensive verification is required across the full range of possible conditions and some parameter adjustment may be needed to avoid inappropriate predictions outside the bounds of the original data. Therefore, statistical accuracy relative to the original data may be sacrificed to assure a full range of appropriate predictions. The NAEMS data should provide an appropriate dataset for model parameterization, but other data and published information should be used for establishing the structure and parameters of the EEM and evaluating that EEM for more diverse conditions. This level of rigor in EEM development and evaluation is necessary for national use.

## 3.2.4. ALTERNATIVE APPROACHES FOR $NH_3$ EEM

*Question 4: Does the SAB recommend that EPA consider alternative approaches for developing the draft NH3 EEM that balances the competing needs for a large dataset (to reflect seasonal meteorological conditions) versus incorporating additional site-specific factors that directly affect lagoon emissions. If so, what specific alternative approaches would be appropriate to consider?*

Background:

EPA requested SAB advice on alternative approaches for developing an $NH_3$ EEM that would balance the competing needs for a large dataset (to reflect seasonal meteorological conditions) versus incorporating additional site-specific factors that directly affect lagoon emissions.

Response:

The SAB recommends that EPA consider alternative approaches for developing a $NH_3$ EEM, since the NAEMS data are limited, and since EPA's goal is to develop an EEM that would be broadly applicable across the U.S. for determining emissions from lagoons. There are several options that EPA should consider to enhance their ability to develop a better EEM:

- Reconsider the 75% completeness goals for data. The draft Report states is stated that "A valid monitoring day is one in which 75% of the hourly average data values used to calculate the daily value were valid measurements. An hourly average is considered valid if 75 percent of the data recorded during that hour were valid." EPA should clarify why the goals of 75% of the hourly average data values were deemed critical for determining an hourly average. EPA should also clarify whether it limited this criterion to 75% of the raw data or to 75% of the two 30-min averages. EPA should consider whether or not this criterion is too stringent, given the data limitations. If collected data were of good quality during a particular hour interval, it would be wise to include these data as there are already many gaps in the data used for the development of these EEMs.
- The goal of having 75% of the hourly averages in order to have a valid monitoring day may be biasing and limiting the dataset. A 75% completeness means that as many as 6 hours of data could be missing in a day and it is important to know when data are missing and whether the missing data would bias the daily average. For example, if data were consistently missing at a time period when the emissions might be high or low, then the overall average may be biased in one direction or the other. It is important to note if the missing hourly values were random or if they occurred in some discernible pattern. In addition, EPA should consider using methods to "gap fill" missing data. In many cases, emissions follow very distinct patterns and it is possible to fill in missing data using interpolation or other algorithms that would increase the number of "valid days" available for analysis.

- Consider using the emissions estimated using the bLS method. Since there is a paucity of data in the current dataset, SAB recommends that EPA should consider using the bLS data either instead of the RPM data or in conjunction with the RPM data. There are actually two points to consider here. The first point is the decision to use 30-min emission values, as opposed to using daily values. While doing this does results in a greater number of data points, the use of daily averages may better capture emission trends. As there are large diurnal emission patterns in any given day, this may overshadow predictor variable effects or add more "noise" in the analysis. As stated above, if the 30-min averages are from time periods when the lagoon emissions are typically high or low, this could affect the overall EEM estimate, whereas using a daily emission value may eliminate that potential problem. Additionally, the real drivers of emissions (i.e., lagoon chemistry and biology) change slowly (more in terms of weeks or months, not minutes), therefore it might be better to use daily values in conjunction with the available lagoon chemistry data to build more powerful models (more on this point below).

- The second point deals with the justification for using the RPM data. As stated in the EPA reports: "The EPA used the RPM data because these measurements were obtained using instrumentation and procedures that were similar to EPA's developmental test method OTM-10. The EPA did not use the bLS emissions measurements because these data were collected under the NAEMS to conduct a validation study of the bLS model performance relative to the RPM model. Furthermore, because the RPM emissions dataset is much larger than the bLS dataset, including the bLS measurement in the EEM development dataset would not provide any additional information on lagoon emissions." If daily values are used then the bLS dataset has 285 valid days as opposed to only 69 valid days using the RPM model. There is no scientific basis for using the RPM dataset over the bLS dataset. This is in no way a validation study for the bLS model. In order to conduct a validation study, the true emission values from the source should be known. Because the true emissions are not known from any of the open area sources, it would not be possible to establish which model performed better and which model produced an emission rate closest to the true rate. Therefore, one cannot draw any conclusions as to which model more closely estimated the true emissions from the source. Based on the few published validation studies available, the bLS model has performed very well for open area sources. One found that the bLS model more accurately predicted emissions from open sources than the RPM model (Ro et al., 2011; Ro et al., 2012). In several of the publications the RPM and bLS emissions estimates were very close, therefore it might be possible to fill in missing days by combining the two datasets and eliminating the overlap. This would result in more available days for use in the development of the model.

- <u>Units of emissions estimates.</u> Use of proper units to express the emissions estimates is also a concern. The draft EEMs use kg/30-min as the unit of emissions, but perhaps better relationships could be developed if EPA used kg/ha or kg/live*wt or some other denominator that captured the physical differences of the operations. These variables (lagoon size and animal weight) were included as predictor variables, but it would potentially be better to account for these in the emission unit therefore eliminating the need to have them as a predictor variable, which would use less degrees of freedom.

- <u>Use of available lagoon chemistry data.</u> At present, the predictor variables chosen to estimate emissions are inadequate. The factors that actually drive the emissions (i.e., lagoon characteristics) were not included in any of the analyses. It seems highly unlikely that a suitable methodology could be developed to predict $NH_3$ emissions across the country when (at a minimum) the nitrogen content and pH of the lagoon have not been included as variables in the model. The model should also consider the potential effects of surface crust on emissions. Some of the predictors chosen such as temperature, day of year, and wind speed would certainly have an impact on emissions, but due to differences in lagoon composition and chemistry, the effects would be farm specific and not translatable to other farms. For instance, it is possible to have two farms in the same area, with the same number of animals and same meteorological conditions that have greatly different emissions due to differences in the pH and nitrogen content of the lagoon, as well as preceding manure management system. There does seem to be both nitrogen and pH data available for four of the farms, representing approximately 46% of the 30-min emissions estimates used in the models. If daily emissions estimates were used and the lagoon chemistry data were extrapolated to other days, there may be a suitable dataset that could be used to develop an EEM using both the lagoon characteristics as well as the meteorological data, data; the resulting EEM is expected to be more robust. The SAB finds that developing an EEM that incorporates the lagoon chemistry, meteorological, and farm data would be much more valid than relying on weather data and static predictor farm variables alone, even though the dataset would be smaller.

- One other concern related to the development of the EEMs using the current technique is that there is no recognition of realistic biological thresholds. Estimates from any models should not violate biological boundaries (i.e., one cannot emit more nitrogen than is present). There should be some upper and lower threshold limits to ensure that, the methodology alone would not result in an estimated emission rate that is not realistic. SAB also recommends that EPA compare the results of the EEMs that it develops with emissions documented in available literature. There are a number of models available that are used to estimate $NH_3$ emissions. One could use the nitrogen and weather information available for the lagoons, attempt to calculate emission rates and compare that with published emission estimates from the literature.

### 3.1. Primary and secondary units

Emission unit is influenced by the type of facility and final use of the data. Primary emission units are directly from the measurements on-farm with secondary units available based on parameters collected to allow conversion from one emission expression to another. The uncertainty associated with the measurements needs to be reported (see Natural Resource Conservation Service (NRCS) White Paper "Methodologies and Protocols for Analysis of Raw Data to Minimize Uncertainty of Resultant Emissions Estimation" for details of uncertainty analysis and expression). The following are five potential expressions of Emission Rate (ER), defined as contaminant mass per unit time for types of source. Some examples are provided for situations in which they are most useful.

1. Per Farm (e.g., ER/500-cow-dairy); Not commonly used due to complexity of accounting for all emission sources under various management options, weather, and geographical differences.

2. Per Unit of Area (e.g., ER/$m^2$) for animal housing, open lots, manure storage, and feed storage; most common for emissions that do not originate from a fully enclosed building.

3. Per Animal Unit (e.g., ER/bird) for animal, place (i.e., # stalls), body weight, productive animal ["per milking cow" = lactating/dry cow + her replacements]; Very commonly used for enclosed buildings or where the animal population is relatively stable in both number and body weight.

4. Per Unit of Food Product (e.g., ER/lb pork, gallon of milk, dozen eggs, or weaned piglet) for final food product or animals marketed; Increasing in use as animal agriculture has become more efficient in product produced with reduced animal population.
5. Per Inputs (e.g., ER/kg nitrogen fed). Best use in models and pollutant mitigation where the biological, chemical, and management influences can be fairly evaluated.

## 3.2.5. COMMENTS ON APPROACH FOR HANDLING NEGATIVE AND ZERO DATA

*Question 5: Please comment on the EPA's approach for handling negative or zero emission measurements.*

Background:

Some NAEMS emissions measurements were reported as either negative or zero emissions values. EPA considered whether to include these negative and zero emissions values in the data used to develop the EEMs. EPA evaluated whether the negative or zero values represented variability in emissions measurements due to instrument/equipment performance. EPA also reviewed the data to see if the data quality measures were properly performed according to the Quality Assurance Project Plan. EPA concluded that all negative values should not be considered in the development of the EEMs.

Response:

*1. Overview*

There are two types of data assessed in EPA's Reports, directly measured air pollutant concentrations and calculated air emission rate values. In both cases, EPA must address negative and zero values. In the draft EEMs, EPA has withheld the negative values in their EEM development process and kept the zero values. SAB has reviewed EPA's treatment of these values and provides the following suggestions for the handling of negative and zero data for both direct concentration measurement and calculated emission values.

*2. Negative values*

There was a relatively small number (<1.7% for broiler and <2% for swine and dairy lagoon data) of negative data points, but their inclusion in the model is important. Negative values appear in both direct concentration measurements and calculated air emission rates. SAB's suggested approaches for handling the negative values are discussed in the following sections.

*2.1. Direct Air Pollutant Concentration Measurement Values*

Except in a few possible situations, negative measures of concentrations are problematic. In general, a negative concentration measurement value can occur due to a true value that is at or below the minimum detection level (MDL), instrument measurement error, a measurement value that is adjusted by the equipment calibration offset procedure, and instrument fluctuation due to influence by ambient conditions. Each of these cases is considered individually.

*Minimum Detection Level and Instrument Error*. From a statistical point of view, the correct approach for dealing with negative values is to recognize that those values are censored. That is, it is known that the measured value is below the instrument's minimum limits of detection, but above zero (a true concentration can never be below zero). As long the rest of the variables associated with that measurement are known (e.g., time of data collection, location, and source type), these censored values should be included in all statistical analyses. In practice, different approximations for dealing with censored responses are often proposed in lieu of the implementation of censored data methods. For instance, if the instrument produces a negative concentration value that is due to a below detection or minimum detection limit reading, but within instrument uncertainty boundaries, the measured value should be used. However, if the measured concentration value is not within acceptable instrument error, then the value should be removed from data set. Suggestions on the treatment of negative values from instrument:

- Use the negative value produced if it is within instrument error.
- Use the EPA procedure of using half of the MDL when the observed value is below the MDL. (Theoretically this method is better, but also very difficult to differentiate the negative values that are due to calibration offset from those that are below the MDL. Accept all negative values that are deemed valid as is.)

*Calibration Offset*. Negative values can arise due to instrument "noise" or adjustment of calibration offset, which is calculated based on the average zero and span values over a period of time. The negative gas concentration values attained during offset correction should generally be very small in comparison with the mean measurement values. Due to the nature of equipment noise, the resulting measurement values can be both positive and negative. Since there is no way to identify the positive noise, the negative noise measurement should be kept for non-biased statistical analysis.

*Ambient Influence*. Variability in instrument measurements can result from variations in ambient conditions (i.e., atmospheric stability) resulting in overestimated positive or negative values. The bias, either positive or negative, will depend on the instrument type (particulate matter or gas) and ambient condition. For example, in the measurement of particulate matter (PM) from broiler confinement housing, negative PM concentrations can occur due to short term fluctuations in relative humidity which causes fluctuation in the real-time TEOM PM concentration measurement process. When the air humidity increases, the TEOM measurement will have an increased bias. If the air humidity decreases, then the TEOM measurement bias will decrease, and a negative PM concentration can possibly occur. Since it is very difficult to identify and quantify the positive bias, the negative bias measurement should be kept for non-biased statistical analysis. Additionally, when measuring the concentration of gas emissions from dairy and swine lagoons, the influence of wind speed and direction can also cause a bias in the data set by influencing the plume direction and velocity. For instance, when wind velocity is negligible, the emission plume will be closer to vertical, resulting in very low concentration measurements, possibly below the MDL. Variable wind direction can also move the plume out of the measurement pathway and cause depressed measurement values. In all cases, negative values can arise. These values are a limitation of the measurement technique, should be screened for validity, and likely excluded from the dataset. In all cases, the negative values that are produced from the situations described above will introduce a bias to the dataset, likely small. If excluded from the data set, standard errors of estimated model parameters will be underestimated and consequently, confidence intervals around, for example, predicted concentrations, will be too narrow, indicating a precision that is higher than what it should be.

In all cases, the negative values that are produced from the situations described above will introduce a bias to the data set, likely small. If excluded from the data set, standard errors of estimated model parameters will be underestimated and consequently, confidence intervals around, for example, predicted concentrations, will be too narrow, indicating a precision that is higher than what it should be.

Overall, it is important to qualify unexpected observations individually and to understand and document why an observation is negative. In some cases, it will be decided that the measurement is the result of operator error, instrument failure, instrument drift or some other factor. In these cases, and absent additional information that might permit correcting the measurement, observations should be discarded.

*2.2. Calculated Emission Rate Data*

Air emission rates were calculated by subtracting the measured background concentration value from the directly measured concentration value, and multiplying by the airflow rate. In cases in which that calculated value was negative, the EPA decided not to include it in the model because they thought it suggested that the area in question (i.e., confinement houses, lagoon), was acting as a sink (EPA, 2012, pg 3). SAB concludes that negative calculated emission data should be included in the model under certain conditions.

Negative calculated emission values can arise from the following scenarios:

- In this study, the background and source measurements were measured either intermittently (twice a day for gas), or continuously without correction for lag time in the barn (PM data), thus leading to a bias either up or down, introducing the potential for negative emission values. Because bias could occur in either the positive or negative direction, negative calculated emission values should be retained in the data set, as long as their individual measured value was already validated. Omitting these data would bias the model in the upward direction. The true estimated value is more accurate if all calculated values are included.
- A calculation bias may also occur when the measured values are at or near the detection limit, or negative. Calculation of negative emission rates due to small or negative values should be very small, and should be kept.
- In some scenarios, outdoor events may affect the background concentration. For example, if there was activity outside the poultry barn which resulted in increased pollutant concentration (e.g., other barn cleanout and manure movement), the measured background values would be biased upwards, and subsequently, the calculated emission value may become negative. Alternatively, a positive bias could occur if meteorological conditions caused the exhaust air to come back into the barn, thus influencing the measured concentration. In these situations, errors caused by special abnormal outdoor events should be identified and removed from the study results if appropriate.

Negative emission rates can be used to develop a model that never predicts negative emissions. In some cases, these negative emission rates may be necessary to appropriately describe the uncertainty of the model. If the prediction model excludes negative values, predictions at low emission rates will be biased, thus weakening the case for use of the EEM.

Overall, SAB suggests that if the measured concentration data are validated and included in the data set, then the emission value calculated from that data set is also valid, whether it is negative or positive.

## *3. Zero values*

Zero values are present in the direct measurement data as well as in the calculated emissions data set. The following discussion provides SAB's recommendations on how to address zero values.

*3.1. Direct Air Pollutant Concentration Measurement Values*

If during measurement, or after instrument calibration, the resulting measurement is zero, SAB recommends that the value ought to be used in statistical analyses. However, few instruments have the precision needed to distinguish a true zero from a small value; consequently, zero measurements will often correspond to censored observations and thus should be treated as such. The use of zero values in the model is likely to produce small biases in both the estimated regression coefficients and their standard errors.

*3.2. Calculated/Emission Data*

After elimination of invalid data, if a calculated emission value is zero, it should be included in the data set. There are many cases in which emissions of a given pollutant may be zero from a particular source and should be included in any analysis. Overall, if the emission value, calculated from valid data, is zero, then that value should always be included in the model.

## *4. Outliers*

EPA did not subject the data to a statistical outlier test; rather, EPA applied standard procedures to flag data believed to be outliers (EPA, 2012, pg 2). SAB suggests that outlier analysis procedures be conducted.

An outlier is an observation that appears to be different from the other observations in the sample. The definition of what makes an observation an outlier is observer-dependent; what appears to be an outlier to one individual may appear to be unremarkable to another.

Outliers can arise for various reasons. Typically, outliers result from faulty measurements, unusual conditions, or data entry error. However, outliers can also indicate the existence of legitimate events with very low probability. If the former, outliers ought to be corrected if possible and discarded otherwise. If the latter, outliers can provide useful insight into the process and lead to revised sampling and modeling approaches.

Unfortunately, it is sometimes difficult to determine whether an outlier is due to a mistake or whether it is an unusual observation with low probability. In those cases, two analyses are often presented, one including and one excluding the outliers, so that users get a sense of the differences in the final conclusions of the analyses that result as a consequence of the unusual observations.

In summary, outliers should be first treated per the QA/QC process to determine (if possible) their origin and then included or not in the analyses with a clear explanation for the decisions made by the analyst.

## *5. References*

EPA. 2012. Attachment A: Discussion of Negative Emissions Values for Broiler Confinement Houses and Swine and Dairy Lagoons/Basins.

## 3.2.6. ALTERNATIVE APPROACHES FOR NEGATIVE AND ZERO DATA

*Question 6: In the interest of maximizing the number of available data values for development of the draft H2S EEMs for swine and dairy lagoons/basins, does SAB recommend any alternative approaches for handling negative and zero data other than the approach used by the agency.*

**Response:** It is understood that the dataset for hydrogen sulfide ($H_2S$) for swine and dairy lagoons/basins was small due to data summary methods and/or instrument deficiency in being able to record concentration/emission values and producing invalid data for $H_2S$. Instrument deficiency was due to changes in wind direction, inadequate wind speeds, or other unknown variables. This cannot be corrected for after the fact. The EPA Reports should fully discuss the occurrence and reasons for the lack of sufficient data and large amount of poor quality data.

The summary methods used by EPA ended up precluding data if a 75% validation level for various time periods (i.e., hourly, daily, total) was not met. The 75% number seemed too stringent and unnecessary in this case and it is suggested that the number be evaluated for reduction or removal so that more data can be included. To maximize the data set, it is recommended that all data meeting the criteria outlined in Charge Question #5 be included for analysis, regardless of the 75% completeness criterion.

See response in Charge Question 5 for general recommendations for handling negative and zero data for any data set.

### 3.2.7. BROILER VOC EEM

*Question 7: Please comment on the approach EPA used to develop the draft broiler VOC EEM.*

<u>Background:</u>

EPA reviewed the volatile organic compound (VOC) data submitted for the California and Kentucky broiler sites. The two sites used different VOC measurement techniques. Based on analysis of the measurement and analytical techniques and the VOC data, EPA used only the VOC data from the Kentucky sites when developing the draft VOC EEM.

<u>Response:</u>

SAB has identified significant limitations with the broiler VOC data, and concluded that the broiler VOC data cannot support the development of a broiler VOC EEM at this time.

Under the Consent Agreement, EPA is required to provide an EEM for daily and annual VOC emissions; however, there is a provision in the Consent Agreement that, if the SAB decides that the available data are not adequate to support development of the EEM, the EPA can delay development until adequate data are available (see *Federal Register* Notice Volume 70, Number 60, Pages 4958-4977, published on January 31, 2005). Limitations of the broiler VOC data include:

- The procedures used to collect VOC data at Site CA1B (i.e., THM analyzer with photobooster) did not produce useful data for model development and should not be used in development of an EEM. Therefore, data from only two farms in one geographic region (KY1B-1 and KY1B-2) are available to EPA through the NAEMS study.

- Canisters, which can only be used to assess a limited suite of compounds, were used to sample VOCs. Other sampling techniques are required to gather other VOCs that cannot be analyzed using canister analysis.

- From Site KY1B, VOC recovery rates from the canister are unknown as not all compounds are able to be extracted from electropolished canisters onto sorbent tubes, and sorbent tubes were not utilized for direct collection of VOCs.

- Sampling at Site KY1B was conducted quarterly over a 21-month period (i.e., seven collection events), during which time two samplers were placed at the exhaust fans of each of two facilities. However, background samples were not collected at the inlet of the barns, so no data were available from which to determine the net increases in VOC concentrations attributable to the housing facilities.

- VOC concentration data from Site KY1B are limited to the specific climate and management conditions of the site and cannot be applied to all production facilities across the U.S. with a reasonable degree of confidence regarding their representativeness.

Based on these concerns, SAB recommends that EPA not generate an EEM for VOCs from broiler operations at this time.

Although the NAEMS data set is too limited to produce an EEM, valuable components of the VOC data should be reported. Based on EPA's presentation of KY1B VOC data, those data appear generally valid and usable if (and only if) the methods used to collect VOC data are more extensively and clearly documented than in EPA's first draft report. In the draft report, the agency reported in detail how data were *supposed* to be collected at both sites, but details of how and what data were *actually* collected were incomplete and unclear. EPA should state unambiguously what data were actually collected from each site, how they were collected and analyzed, and what data passed QA/QC criteria checks. Data collected absent strict adherence to SOP and QAPP including equipment calibration methods are not valid and should be identified as such.

Data reported by the EPA should include total and speciated VOC concentrations to provide general information on broiler emissions from the sites where data were collected. Moreover, "Total VOCs" should be explicitly defined to clarify whether reported values represent the sum of all VOCs analyzed or the total VOCs quantified by the analyzer, which will capture only a portion of all VOCs present in a sample. These data may help identify important compounds emitted from broiler facilities, which can help guide future data collection efforts. An indication of the magnitude of VOC concentrations relative to any reports of background VOC concentrations reported for this region would help, qualitatively, to identify those compounds that appear to be emitted in substantial quantities from the CAFOs. One challenge with the incomplete data collection is how EPA determines "substantial quantities of compounds are emitted" when then entire VOC suite emitted is not quantified; when such quantification does not occur, it is not possible to identify if one compound or another is a substantial component of VOC emitted. Also, the determination of what is 'substantial' is subjective without numeric qualifier. After reporting the available data, the EPA should defend the decision to not develop an EEM given the limited information available and the uncertainty of the data collected in the NAEMS. In order to develop an EEM for VOCs, a comprehensive investigation from existing scientific literature and future research regarding what factors drive generation of VOC emissions from broiler facilities is necessary to lay the foundation for development of a process-based model for estimating emissions from these operations.

# 4. SPECIFIC RECOMMENDATIONS FOR EPA'S DRAFT REPORTS

The SAB provides the following general comments on EPA's two draft documents related to animal feeding operations emissions: "Development of Emissions-Estimating Methodologies for Broiler Animal Feeding Operations" (i.e., Broiler Report), and "Development of Emissions-Estimating Methodologies for Lagoons and Basins at Swine and Dairy Animal Feeding Operations" (i.e., Lagoon Report). SAB considered whether the draft Broiler and Lagoon Reports were presented in a clear, comprehensive, and scientifically sound manner.

Overall, SAB finds that both Reports should be updated to describe the importance of retaining a long-term goal for producing process-based models. The SAB also concludes that the Reports should more comprehensively describe data completeness, representativeness, and limitations, and whether there are sufficient data to begin a process-based modeling approach. In addition, SAB recommends that the discussions on mechanisms of data collection, ventilation rates within barns, and feed composition and quantity should be enhanced in the Reports. Furthermore, the Reports should more fully explain why any of the NAEMS data were excluded from EEM development. Since NAEMS data have significant limitations, the Reports should include an assessment that considers use of additional data that were not collected as part of the NAEMS data collection effort.

Specific SAB recommendations for each draft report, beyond those made in response to the charge questions, are noted below.

**<u>Draft EPA Broiler Report</u>**

SAB recommends that EPA reorganize the report and rewrite several sections to address various concerns of the SAB. EPA should develop a process-based modeling approach to make predictions of air emissions on broiler farms, and incorporate that approach into the report. EPA should also make a number of improvements to the statistical approach for developing EEMs. In particular, EPA should describe methods for calculating confidence values to present variability of data, include quantitative statistical analyses that compare houses, consider approaches in addition to the cross-validation method used to evaluate the model, and more comprehensively describe data completeness, representativeness, and limitations.

Section 1 should describe the importance of pursuing a long-term goal of producing process-based models and refer to the National Research Council (NRC, 2003) recommendations on this topic. This section should also note that the development of the current models is considered a short-term tool with limited application for estimating emissions.

The limitations of the data set and the various data measurement problems that occurred as part of the NAEMS data collection efforts should be more comprehensively described and summarized in Section 1. For example, data from poultry sites were collected for typical bird grow-out periods, but there are birds (e.g., Cornish hens) that are grown for much shorter periods and those (e.g., large roasters) that are grown for much longer periods. These limitations should be clearly stated because the current EEMs for ammonia would not fit some of the situations well at all (i.e., emissions would be estimated to go to zero for some of the largest birds and would be negative for some of the smallest birds). The discussion on mechanisms of data collection, ventilation rates within barns, and feed nutrients consumed should also be enhanced.

The introduction section should also clearly acknowledge that the broiler data were collected at an extremely limited number of study sites (four broiler barns on three farms). EPA should consider clarifying the text to note that the 2,600 industrial participants in the Consent Agreement are a very small fraction of the one-half million AFOs in the country. EPA should also consider clarifying what percentage of total confinement animal production that these industrial participants represent.

The text in this section, or in Section 2, would be strengthened by referral to the mechanistic processes behind the EEMs that EPA employed. This section should describe the primary physical/biological/ chemical mechanisms that lead to emissions of each regulated parameter in relation to the surrogate statistical parameter to strengthen the validity of the statistical model that was employed. For example, the product of bird number and mass is considered a surrogate for fresh manure production that impacts ammonia emissions.

The text should note that EPA planned to measure several key parameters that would affect emissions generation, such as animal activity (perhaps assessed through lighting program hours for light and dark periods), diets, feed rate and composition, water management, manure composition (moisture and nitrogen), feed composition including total nitrogen that result in releases of gaseous pollutants, total number of animals, and ventilation rate. The text should note that EPA did not utilize these parameters during EEM development because EPA judged that data for these variables were insufficient in quantity and/or quality. EPA should describe data that had been collected but not yet transmitted to EPA as of the development of the EEMs.

The accurate determination of ventilation rate (VR) is a very important aspect of the NAEMS data collection and is necessary to achieve representative emission data. The determination of accurate ventilation rate should be given more prominence in the report with a concise description of how this was achieved. The description of ventilation systems and control operations for each barn also should be clarified, particularly regarding inlet description and function.

EPA should also clarify the range of conditions under which the NAEMS-based EEMs can be used. For example, EPA should describe the ambient temperature range during grow- out or litter management period between flocks within which the EEMs can be applied. EPA should also add cautionary notes regarding the use of EEMs outside of the studied range.

The report should note that that broiler houses are commonly managed as both bird production facilities and as dry manure storage if litter is not completely cleaned out between flocks. It should also discuss the importance of stockpiled litter storage emission measurements (litter being the combination of bedding and manure) and the link of such emissions to the process-based model development. The microbial degradation and natural chemical interactions associated with all the parameters measured should be described. Throughout the report, the emissions from populated houses during grow-out and empty houses during litter management should be presented separately since the house is managed very differently during these two time periods. In addition, the differential in emissions observed from fully cleaned out houses versus de-caked, built-up litter houses should be presented separately.

EPA should improve the clarity of the discussions on the NAEMS monitoring sites and on the data available for EEM development. EPA should discuss why the data sets that were used can be considered representative of the industry and the literature. For example, it is unclear how well house CA1B, built in the 1960s, represents modern industry practices. Also, pancake brooders (used in KY) are primarily used by one integrator. EPA should develop criteria for considering additional data and how to use such data.

EPA describes many parameters that were not used in its analysis. EPA should clarify which parameters were used for developing EEMs and discuss the reasons for, and the importance of, not including in the analysis certain parameters for which data were collected in its analysis.

EPA should provide the following additional information regarding the data used in developing EEMs:

- Identify the number of samples that collected at each sampling event and the periods that data were collected.
- Clarify the VOC discussions regarding Kentucky and California VOC analyses. This discussion is poorly written and very confusing. EPA should note that the California VOC data were not used and why these data were not used.
- Describe fan calibration procedures and frequency.
- Clarify how the change in purge time for first 4 months of gas sampling in CA was addressed.
- Describe PM sampling schedule for PM10, PM2.5 and TSP samples .
- Explain what data were to be collected in the sampling plan.
- Describe inlet systems used for measurement, and associated issues.
- Describe ventilation rate which includes discussion on the FANS system and repeated calibrations.

EPA should clearly specify criteria for data completeness, how data can be used, eliminating data, how background concentration data were collected, and use of data available in the literature for a modeling verification effort. EPA should also discuss why a 75% completeness value was used as a threshold for using data, why there are missing data days, and why some data were collected in some seasons and not in others. EPA should also clarify how EPA identified outliers in the data and the reasons for their inclusion or omission. The discussion on seasonal influences should be improved to discuss whether such influences should be incorporated into the model. The text should also describe how anomalies are defined and applied in the data set.

## Draft EPA Lagoon Report

SAB recommends that EPA reorganize the report and rewrite several sections to address various concerns of the SAB. Various recommendations are provided to more comprehensively describe data completeness, representativeness, and limitations. In addition, many comments that SAB provides to the Broiler Report also apply to the Lagoon Report (e.g., comments on data completeness, use of data, and statistical and process-based model approaches). EPA should review the Lagoon report and incorporate such comments as appropriate.

Section 1 should describe the importance of pursuing a long-term goal for developing process-based models, and refer to the NRC (2003) recommendations on this topic. This section should also note that the development of empirical models is considered a short-term tool for estimating emissions.

The discussion on the U.S. dairy and swine industries should be rewritten . This section notes that due to the limited amount of nitrogen content, solid content and pH of the lagoon liquid, these data were not included in the EEM. Section 2 also notes that data on manure residence time, amount of sulfur ingested by an animal, and amount of carbon in feed were not collected. The limitations of the data set and the various data measurement problems that occurred as part of the NAEMS data collection efforts should be summarized.

The discussion on manure management, storage and stabilization should be revised. EPA's discussion on the design difference between storage and treatment ponds (i.e., basins and lagoons, respectively) is inconsistent and incorrect; treatment ponds are designed specifically for biological treatment, and storage ponds are not designed for biological treatment. In addition, waste characteristics for swine and dairy animals are significantly different. Standardized definitions exist for manure treatment/storage structures; EPA and the NAEMS scientists should use ASAE Standard: Uniform Terminology for Rural Waste Management (ASABE S292.5). The text should describe the processes that generate ammonia from nitrogen and that cause volatilization of that nitrogen. The text should also describe the microbial degradation and natural chemical interactions for all parameters measured.

The report should be rewritten to include additional details on the dairy and swine industry, in particular the waste handling techniques and manure characteristics. Additional details on hydrocarbon and VOC sampling results, average dairy cow weight, and manure management systems should be provided. Additional information on the lagoons where data were collected should be provided, as well as information on what constitutes a standard lagoon throughout the industry. In addition, it should be noted that EPA's analysis used data from a wash water dairy lagoon, not a manure storage lagoon, which may affect the EEM estimation efforts.

EPA should specify reasons for selecting criteria for data completeness, how data can be used, criteria for eliminating data, how background data were collected, and use of data available in the literature for a modeling verification effort. EPA should also clarify how outliers were identified and the reasons for their inclusion or omission.

**References for Broiler and Lagoon Reports:**

SAB suggests that EPA consider the following additional references to improve the literature base for the draft EPA Reports and help ensure a more comprehensive understanding of AFO broiler and/or swine and dairy lagoon/basin operations:

Aneja, V. P., S. Pal Arya, D.S. Kim, I.C. Rumsey, H.L. Arkinson, H. Semunegus, K.S. Bajwa, D.A. Dickey, L.A. Stefanski, L. Todd, K. Mottus, W.P. Robarge, and C.M. Williams. 2008. Characterizing

Ammonia Emissions from Swine Farms in Eastern North Carolina: Part 1—Conventional Lagoon and Spray Technology for Waste Treatment. J. Air & Waste Manage. Assoc. 58:1130–1144.

Aneja, V. P., S.P. Arya, I.C. Rumsey, D.S. Kim, K. Bajwa, H.L. Arkinson, H. Semunegus, D.A. Dickey, L.A. Stefanski, L. Todd, K. Mottus, W.P. Robarge, and C.M. Williams. 2008. Characterizing Ammonia Emissions from Swine Farms in Eastern North Carolina: Part 2—Potential Environmentally Superior Technologies for Waste Treatment. J. Air & Waste Manage. Assoc. 58:1145–1157.

Aneja, V. P., S.P. Arya, I.C. Rumsey, D-S. Kim, K.S. Bajwa, and C.M. Williams. 2008. Characterizing ammonia emissions from swine farms in eastern North Carolina: Reduction of emissions from water-holding structures at two candidate superior technologies for waste treatment. Atmospheric Environment 42: 3291–3300.

Aneja, V. P., J.P. Chauhan, and J.T. Walker. 2000. Characterization of atmospheric ammonia emissions from swine waste storage and treatment lagoons. J. of Geophysical Research 105 (No. D9): 11535–11545.

Aneja, V. P., W.H. Schlesinger, and J. Willemerisman. 2009. Effects of agriculture upon the air quality and climate: research, policy, and regulations. Environ. Sci. Technol. 43, 4234–4240.

ASABE. 2005. Manure Production and Characteristics. ASABE Standard D384.2. St. Joseph.

Bajwa, K.S., V.P. Aneja, and S.P. Arya. 2006. Measurement and estimation of ammonia emissions from lagoon–atmosphere interface using a coupled mass transfer and chemical reactions model, and an equilibrium model. Atmospheric Environment 40: S275–S286.

Blunden, J. and V.P. Aneja. 2008. Characterizing ammonia and hydrogen sulfide emissions from a swine waste treatment lagoon in North Carolina. Atmospheric Environment 42: 3277–3290.

Blunden, J., V.P. Aneja, and J.H. Overton. 2008. Modeling hydrogen sulfide emissions across the gas–liquid interface of an anaerobic swine waste treatment storage system. Atmospheric Environment 42: 5602– 5611.

Blunden, J., V.P. Aneja, and P.W. Westerman. 2008. Measurement and analysis of ammonia and hydrogen sulfide emissions from a mechanically ventilated swine confinement building in North Carolina. Atmospheric Environment 42: 3315–3331.

Blunden, J., V.P. Aneja, and W.A. Lonneman. 2005. Characterization of non-methane volatile organic compounds at swine facilities in eastern North Carolina. Atmospheric Environment 39: 6707–6718.

Burns, R.T., H. Xin, R.S. Gates, H. Li, L.B. Moody, D.G. Overhults, J.W. Earnest, S.J. Hoff, and S. Trabue. 2009. Final project report on Southeastern broiler gaseous and particulate matter emissions monitoring.

Coufal, C.D., C. Chavez, P.R. Niemeyer, and J.B. Carey. 2006. Effects of top-dressing recycled broiler litter on litter production, litter characteristics, and nitrogen mass balance. Poultry Sci. 85: 392-397.

Coufal, C.D., C. Chavez, P.R. Niemeyer, and J.B. Carey. 2006. Measurement of broiler litter production rates and nutrient content using recycled litter. Poultry Sci. 85: 398-403.

Coufal, C.D., C. Chavez, P.R. Niemeyer, and J.B. Carey. 2006. Nitrogen emissions from broilers measured by mass balance over eighteen consecutive flocks. Poultry Sci. 85: 384-391.

Flood, C. A., J. L. Koon, R. D. Trumbull, and R. N. Brewer. 1992. Broiler growth data: 1986–1991. Trans. ASAE 35(2): 703–709.

Lacey, R.E., J.S. Redwine, and C.B. Parnell. 2003. Particulate matter and ammonia emission factors for tunnel-ventilated broiler production houses in the southern U.S. *Transactions of the ASAE* 46(4): 1203-1214.

Malone, G. W., T. Sims, and N. Gedamu. 1992. Quantity and quality of poultry manure produced under current management programs. Final report to the Delaware Department of Natural Resources and Environmental Control and Delmarva Poultry Industry, Inc., University of Delaware, Research and Education Center, Georgetown, Delaware.

Metcalf and Eddy. 2003. Wastewater Engineering: Treatment and Reuse. 4th ed. New Tork: McGraw-Hill.

Mosquera, J. and N.W.M. Ognik. 2004. Determination of the variation sources associated with ammonia emission measurements of animal housings.  AgEngr 2004. Leuven, Belgium.

National Research Council (NRC). 2003. Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. Washington, DC: The National Academies Press.

Natural Resource, Agriculture, and Engineering Service (NRAES). 1999. Poultry Waste Management Handbook. Coop. Extension, Ithaca, NY.

Natural Resource Conservation Service (NRCS) White Paper "Methodologies and Protocols for Analysis of Raw Data to Minimize Uncertainty of Resultant Emissions Estimation".  2010.  Xin, H.; Li, H.; Gates, R.; Burns, R.;  and Casey, K. http://yosemite.epa.gov/sab/sabproduct.nsf/C86C8E839E06C34C852579BA006D31A1/$File/Public+Comments+submitted+by+Sally+Shaver+and+Dr.+Robert+Burns,+representing+the+USDA+Ag+Air+Quality+Task+Force-3-7-12.pdf

Ogink, N.W.M., J. Mosquera, R.W. Melse.  2008. Standardized testing procedures for assessing ammonia and odor emissions from animal housing systems in The Netherlands In: Proceedings of the Mitigating Air Emissions from Animal Feeding Operations Conference, Des Moines, Iowa, USA, 19 - 21 May, 2005. - Des Moines : Mitigating Air Emissions from Animal Feeding Operations Conference, 2008-05-19/ 2008-05-21

Redwine, J.S., R.E. Lacey, S. Mukhtar, and J.B. Carey. 2002. Concentration and emissions of ammonia and particulate matter in tunnel-ventilated broiler houses under summer conditions in Texas. *Transactions of ASAE* 45(4): 1101-1109.

Ro, K. S., M.H. Johnson, P. G. Hunt, and T. K. Flesch. 2011. Measuring trace gas emission from multi-distributed sources using vertical radial plumemapping (VRPM) and backward Lagrangian stochastic (bLS) techniques. Atmosphere 2(3): 553-566.

Ro, K. S., M.H. Johnson, K.C. Stone, P.G. Hunt, T. K. Flesch, and R.W. Todd. 2012. Inverse-dispersion technique for assessing lagoon gas emissions. American Society of Agricultural and Biological Engineers, 2012 Conference Proceedings, Dallas, Texas, July 29 - August 1, 2012.

Rumsey, I. C., V.P. Aneja, and W.A. Lonneman. 2012. Characterizing non-methane volatile organic compounds emissions from a swine concentrated animal feeding operation. Atmospheric Environment 47: 348-357.

South Coast Air Management District has had emissions estimates for dairy in poultry for years. SCAQMD Poultry and Dairy Emission factors and guidelines for using the online ‘calculator’ can be found here: www.aqmd.gov/aer/Updates/GuideCalcEmisDairyPoultry.pdf (January 2009).

Summers, M. D. 2005. FINAL REPORT: Quantification of Gaseous Emissions from California Broiler Production Houses. Available at: http://www.arb.ca.gov/ag/caf/poulemisrpt.pdf accessed 29 March 2012.

Trabue, S., K. Scoggin, H. Li, R. Burns, H. Xin, J. Hatfield. 2010. Speciation of volatile organic compounds from poultry production. Atmospheric Environment 44: 3538-3546.

Vega, E., E. Reyes, A. Wellens, G. Sanchez, J.C. Chow, and J.G. Watson. 2003. Comparison of continuous and filter based mass measurements in Mexico City. Atmospheric Environment 37: 2783-2793.

Wheeler, E.F.; Meyer, D.; Martin, P.; Schmidt, D.; and Powers, W. 2010. Recommended Units and Supporting Data for Standardized Reporting of Air Emissions from Animal Agriculture White Paper USDA NRCS Agricultural Air Quality Task Force. 21 September 2010 Livestock and Poultry Sub-Committee.
http://yosemite.epa.gov/sab/sabproduct.nsf/C86C8E839E06C34C852579BA006D31A1/$File/Public+Comments+submitted+by+Sally+Shaver+and+Dr.+Robert+Burns,+representing+the+USDA+Ag+Air+Quality+Task+Force-3-7-12.pdf

**Appendices:**

The Appendices reference several pre-study validation studies. The results from these validation studies should be included in the Report so that it is possible to evaluate the data quality that may have been generated using these tested techniques.

# APPENDIX A – EPA'S CHARGE QUESTIONS

February 17, 2012

**MEMORANDUM**

**SUBJECT:** Animal Feeding Operations Air Emissions Estimating Methodologies from the National Air Emissions Monitoring Study

**FROM:** Stephen D. Page, Director
Office of Air Quality Planning and Standards (C404-04)

**TO:** Ed Hanlon
Designated Federal Officer
Animal Feeding Operations Emission Review Panel
EPA Science Advisory Board Staff Office (1400R)

This memorandum requests that the Science Advisory Board (SAB) review and comment on the draft emissions estimating methodologies (EEMs) for animal feeding operations (AFOs). In preparation for this review, the SAB has formed the *Animal Feeding Operations Emission Review Panel*. We envision conducting multiple meetings of this panel to cover the material we are requesting to be reviewed. This memorandum contains background material and charge questions for review by the expert SAB Panel at the initial meeting. We request that these materials be forwarded to the SAB Panel for their review.

As the attachment and associated documents illustrate, the EPA staff has carefully considered the data collected as part of the National Air Emissions Monitoring Study (NAEMS) and now ask the Panel to refine and comment upon our work thus far to create EEMs. To bound and define the discussion, the attachment offers charge questions for the Panel to consider.

By way of background, in 2005, the EPA entered a voluntary consent agreement with the AFO industry in which AFOs that chose to sign the Air Compliance Agreement (Agreement) shared responsibility for funding a nationwide emissions monitoring study. The NAEMS monitoring protocol was developed through a collaborative effort of AFO industry experts, university scientists, U.S. Department of Agriculture and EPA scientists and other stakeholders. The monitoring study was designed to gather data for developing methodologies for estimating emissions from AFOs and to help AFOs determine and comply with their regulatory responsibilities under the Clean Air Act (CAA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), and the Emergency Planning and Community Right-To-Know Act (EPCRA). Once the EPA publishes the applicable EEMs, the Agreement requires each participating AFO to certify that it is in compliance with all relevant requirements of the CAA, CERCLA and EPCRA.

We appreciate your efforts and those of the Panel to prepare for the upcoming meeting and look forward to discussing this project in detail. Questions regarding the attached materials should be directed to Ms.

Robin Dunkins, EPA-OAQPS (telephone: 919-541-5335; email: dunkins.robin@epa.gov).

Attachment

cc: Bill Harnett
Robin Dunkins
Larry Elmore
Lawrence Elworth
Allison Mayer
Janet McCabe
Peter Tsirigotis

## ATTACHMENT

## Regulatory Background

In 2005, the EPA entered a voluntary consent agreement with the animal feeding operations (AFO) industry in which AFOs that chose to sign the Air Compliance Agreement (Agreement) shared responsibility for funding the National Air Emissions Monitoring Study (NAEMS). Approximately 2,600 AFOs, representing nearly 14,000 facilities that include broiler, dairy, egg layer and swine operations, received the EPA's approval to participate in the Agreement.

To provide a framework for the NAEMS, AFO industry experts, university and government scientists and other stakeholders collaborated to develop a comprehensive monitoring plan. The study was designed to generate scientifically credible data to characterize emissions from the participating animal sectors.

Consistent with the Agreement, the Agriculture Air Research Council (AARC), a nonprofit entity comprised of participating AFO industry representatives, administered the monitoring study. The AARC was responsible for selecting the Independent Monitoring Contractor (IMC) and the study's Science Advisor with EPA approval. The Agreement outlined the roles and responsibilities of the AARC, the IMC and the Science Advisor.

The monitoring plan specified the general geographic location of the farms to be monitored, animal production phase, ventilation type, manure management/handling system and other pertinent information for each animal sector.

- For broilers, two sites were to be monitored - one on the West Coast and the other in the Southeast. Both were to be mechanically ventilated and have litter on the floor.
- For the swine industry, the sites were to be located in the Southeast (sow and finisher), Midwest (sow and finisher), and West (sow). Mechanically-ventilated buildings, a deep pit building, lagoons and basin manure storage types were to be monitored.
- For dairy, both naturally- and mechanically-ventilated buildings, lagoons and basins were monitored. Five dairies were monitored, one dairy in each of the following geographical areas: Northeast, Midwest, Northwest, West and South.

For confinement sources, the IMC monitored for ammonia ($NH_3$), particulate matter ($PM_{10}$, $PM_{2.5}$, TSP), volatile organic compounds (VOCs) and hydrogen sulfide ($H_2S$). For lagoons and basins, $H_2S$, $NH_3$ and VOC were to be monitored. Accordingly, the EPA is then responsible for developing EEMs for each of these pollutants.

## Charge to the Science Advisory Board (SAB) AFO Air Emissions Review Panel

In preparation for the first and second meeting, the EPA has analyzed the NAEMS data for two broiler sites and nine swine and dairy lagoons/basins. For the purpose of this study, the EPA used the description of a lagoon and basin as provided in the MidWest Plan Service "Manure Storages" (MWPS-18 Section 2) document. According to MWPS, "A lagoon is a biological treatment system designed and operated for biodegradation of organic matter in animal manure to a more stable end product. A basin, while similar to but smaller than a lagoon, is designed to store manure only and is not a treatment system."

For a broiler confinement house, the EPA has developed draft EEMs for $NH_3$, $PM_{10}$, $PM_{2.5}$, TSP, VOC and $H_2S$. For swine and dairy lagoons/basins, the EPA has only developed a draft EEM for $NH_3$. The documents provided to the SAB describe the sites monitored; the data submitted to the EPA; and a detailed discussion of the statistical methodology used to develop the draft EEMs. This material is provided to inform the SAB panel of the EEM development process used by the agency. In subsequent meetings, the EPA will address draft EEMs for egg-layers, swine and dairy confinement houses and other pollutants for swine and dairy lagoons/basins.

**Issue 1: Statistical Methodology used to develop draft EEMs**

The EPA seeks the SAB's input on the statistical methodology used by the EPA to develop the draft EEMs. Section 7.0 and 8.0 of the broiler document and section 5.0 of the swine and dairy lagoon/basin document provide an overview of the statistical methodology used to develop the draft EEMs. A flow diagram of the statistical methodology is provided in Figure 7-1 in the broiler document and Figure 5-1 in the swine and dairy lagoon/basin document. The EPA considers this statistical methodology to be the best approach for analyzing the data and intends to use this same approach to develop draft EEMs for the egg-layers, swine and dairy confinement houses.

Using the process described in the sections listed above, we developed a mean trend function that provides a point prediction of emissions under a given set of conditions. We chose an appropriate mean trend function to quantify the relationship between predictor variables and pollutant emissions by analyzing the emissions data and incorporating knowledge of the emissions generating processes. The EEM development process also involves choosing a probability distribution and covariance function to appropriately quantify other contributions to variability in emissions, and thereby to accurately quantify methods at all stages. If necessary, we will adjust the statistical methodology based on our review of the SAB's input.

***Question 1:*** Please comment on the statistical approach used by the EPA for developing the draft EEMs for broiler confinement houses and swine and dairy lagoons/basins. In addition, please comment on using this approach for developing draft EEMs for egg-layers, swine and dairy confinement houses.

**Issue 2: Statistical Methodology used to develop swine and dairy lagoon/basin draft EEMs**

After conducting an initial analysis of the NAEMS data submitted for swine and dairy lagoons/basins, the EPA decided to focus on developing a draft EEM for $NH_3$. The EPA's review of current literature indicates that lagoon/basin emissions are influenced by several factors, one of these being lagoon/basin temperature. To ensure that the dataset used to develop the draft EEM represented all seasonal meteorological conditions for the entire two year monitoring period, the EPA decided to combine the swine and dairy data. Combining the swine and dairy lagoon/basin dataset also resulted in combining lagoon and basin emissions data.

To maximize the number of $NH_3$ emissions measurements used to develop the draft EEM, the EPA used static predictor variables as surrogates for data on lagoon/basin conditions (i.e., nitrogen content of lagoon liquid, lagoon pH, oxidation reduction potential and temperature). The static variables of animal type, total live mass of animal capacity on the farm and the surface area of the lagoon were used to represent $NH_3$ precursor loading and the potential for release to the air. Consistent with operating parameters associated with statistical degrees-of-freedom, we concluded that two degrees of freedom was the maximum that the data would credibly allow for inclusion in the developing the draft EEM. As a result, the EPA developed three sets of draft EEMs, using the paired combinations of these static variables (i.e., animal type, surface area, farm size) and the continuous variables representing meteorological conditions (i.e., temperature, atmospheric pressure, humidity, wind speed, solar radiation).

***Question 2:*** Please comment on the agency's decision to combine the swine and dairy dataset to ensure that all seasonal meteorological conditions are represented. In addition, the agency also seeks the SAB's comments on whether the agency should combine lagoon and basin data.

***Question 3:*** Please comment on the agency's decision to use static predictor variables as surrogates for data on lagoon/basin conditions. Given the uncertainties in that approach, does the SAB recommend that EPA consider specific alternative approaches for statistically analyzing the data that would allow for the site-specific lagoon liquid characteristics to be used as predictor variables?

***Question 4:*** Does the SAB recommend that EPA consider alternative approaches for developing the draft $NH_3$ EEM that balances the competing needs for a large dataset (to reflect seasonal meteorological conditions) versus incorporating additional site-specific factors that directly affect lagoon emissions. If so, what specific alternative approaches would be appropriate to consider?

**Issue 3: Negative and Zero Data**

Some emissions measurements were reported to the EPA as either negative or zero emissions values. When developing the draft EEMs, the EPA used the following general approach regarding inclusion of negative and zero emissions values in the data.

- The EPA evaluated whether the negative or zero values represent the variability in emissions measurements due to the means of obtaining the measurements. For example, negative values for a pollutant concentration might result when the concentration of the pollutant falls below the minimum detection limit of a monitor. For all EEM datasets, the EPA included zero values because these values potentially represent instances where the emissions from the source were zero (e.g., a frozen lagoon), or the background and pollutant concentrations from the source were the same. Regarding negative values, in cases where the dataset available to develop draft EEMs was relatively large and the emissions were significantly greater than zero, the EPA excluded negative emissions values from the EEM datasets. The EPA used this approach to develop the entire broiler confinement house draft EEMs and swine and dairy lagoon/basin $NH_3$ draft EEMs.

- The EPA reviewed the data to see if the data quality measures were properly performed according to the Quality Assurance Project Plan.

- If the EPA identified data where the quality assurance measures were not followed, we contacted the science advisor to determine if the corrected data could be submitted to the EPA.

The EPA has conducted a preliminary analysis of the swine and dairy lagoon/basin $H_2S$ emissions data. Our analysis indicates that we may need to modify our approach for handling negative and zero data in order to develop a draft $H_2S$ EEM for swine and dairy lagoons/basins. A modification may be needed due to the limited number of $H_2S$ emissions values, the presence of a greater percentage of negative emissions values and emissions values that are closer to zero than the $NH_3$ emissions for swine and dairy lagoons/basins. The EPA's concern is that failure to include the negative measurements in the dataset, or setting them equal to zero, would result in an EEM that fails to fully quantify uncertainty around the point prediction of emissions attributable to measurement error.

***Question 5:*** Please comment on the EPA's approach for handling negative or zero emission measurements.
***Question 6:*** In the interest of maximizing the number of available data values for development of the draft $H_2S$ EEMs for swine and dairy lagoons/basins, does SAB recommend any alternative approaches for handling negative and zero data other than the approach used by the agency.

**Issue 4: Volatile Organic Compounds (VOC) Data**

The EPA reviewed the VOC data submitted for the California and Kentucky broiler sites. The two sites used different VOC measurement techniques. Based on our analysis of the measurement and analytical techniques and the VOC data, the EPA decided to use only the VOC data from the Kentucky sites when developing the draft VOC EEM.

***Question 7:*** Please comment on the approach EPA used to develop the draft broiler VOC EEM.