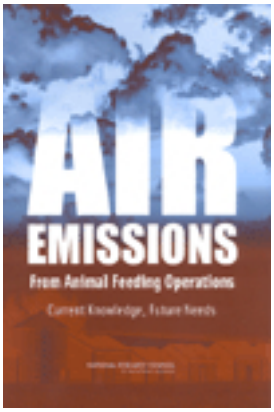
Free Executive Summary



Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs

Ad Hoc Committee on Air Emissions from Animal Feeding Operations, Committee on Animal Nutrition, National Research Council

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Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs discusses the need for the U.S. Environmental Protection Agency to implement a new method for estimating the amount of ammonia, nitrous oxide, methane, and other pollutants emitted from livestock and poultry farms, and for determining how these emissions are dispersed in the atmosphere. The committee calls for the EPA and the U.S. Department of Agriculture to establish a joint council to coordinate and oversee short - and long-term research to estimate emissions from animal feeding operations accurately and to develop mitigation strategies. Their recommendation was for the joint council to focus its efforts first on those pollutants that pose the greatest risk to the environment and public health.

Executive Summary

Public concerns about the environmental effects and, to a lesser extent, the possible health effects of air emissions from animal feeding operations (AFOs, see Appendix B) have grown with the increasing size and geographic concentration of these operations. This intensification has been driven by the economics of domestic and export markets for meat, poultry, milk, and eggs. Public concerns have also grown as the population, both exurbanites and expanding urban centers, have moved into what had been largely rural farming areas. Objectionable odors from AFOs are a significant concern not only to the new residents in these areas, but also to many long-time residents.

Prompted by legislation, especially the Clean Air Act (CAA), as well as by public concerns, the U.S. Environmental Protection Agency (EPA) has been considering what information is needed to define and support feasible regulation of air emissions from AFOs. At the same time, the U.S. Department of Agriculture (USDA) has been using its authority to aid farmers in mitigating the effects of air emissions with modified agricultural practices. Acting jointly, these two agencies asked the Board on Agriculture and Natural Resources (BANR) to evaluate the scientific information needed to address these issues. A 16-person ad hoc committee was appointed, the Committee on Air Emissions from Animal Feeding Operations, which has been guided by a Statement of Task that was agreed upon by the National Academies and the sponsoring agencies (Appendix A).

The Statement of Task directed the committee to

- review and evaluate the scientific basis for estimating the emissions to the atmosphere of various specified substances from confined livestock and poultry operations;

- review the characteristics of the agricultural animal industries, methods for measuring and estimating air emissions, and potential best management practices for mitigating emissions;
- evaluate confined animal feeding production systems in terms of biologic systems; and
- identify critical short- and long-term research needs and recommend methodologic and modeling approaches for estimating and measuring air emissions and potential mitigation technologies.

Making scientifically credible estimates of air emissions from AFOs is complicated by various factors that affect the amounts and dispersion of emissions in the atmosphere. Such factors include the kinds and numbers of animals involved, their diets and housing, the management of their manure (feces and urine, which may also include litter or bedding materials), topography, climatic and weather conditions, and actions taken to mitigate the emissions and their effects. Estimates of emissions generated for one set of conditions or for one type of AFO may not translate readily to others.

Accurate estimation of air emissions from AFOs is needed to gauge their possible adverse impacts and the subsequent implementation of control measures. For example, increasing pressure is being placed on EPA to address these emissions through the Clean Air Act and other federal laws and regulations. EPA is under court order to establish new water quality rules for AFOs by December 2002. The need to understand the relationship between actions to mitigate the effects of manure management on water quality and its related effects on air quality prompted EPA to ask for an interim report several months in advance of this final report. The committee's findings in the interim report (Box ES-1) are encompassed and extended by the findings and recommendations in this report.

The contents, including the findings and recommendations, of this report represent the consensus views of the committee and have been formally reviewed in accordance with National Research Council procedures. In addressing its Statement of Task, the committee has come to consensus on 13 major findings, each accompanied by one or more related recommendations. The basis of these findings is discussed more extensively in the body of the report.

FINDINGS AND RECOMMENDATIONS

Animal Units

EPA defines animal units differently than USDA. An EPA animal unit is equal to 1.0 slaughter and feeder cattle, 0.7 mature dairy cows, 2.5 pigs weighing more than 55 pounds, 10 sheep or lambs, and 0.5 horses. USDA defines animal unit as 454 kg (1000 pounds) of animal live weight regardless of species. A consistent basis for defining animal unit will decrease confusion that may exist be-

BOX ES-1 Findings from the Interim Report (NRC, 2002a)

Finding 1. Proposed EPA regulations aimed at improving water quality may affect rates and distribution of air emissions from animal feeding operations.

Finding 2. In order to understand health and environmental impacts on a variety of spatial scales, estimates of air emissions from AFOs at the individual farm level, and their dependence on management practices, are needed to characterize annual emission inventories for some pollutants and transient downwind spatial distributions and concentrations for others.

Finding 3. Direct measurements of air emissions at all AFOs are not feasible. Nevertheless, measurements on a statistically representative subset of AFOs are needed and will require additional resources to conduct.

Finding 4. Characterizing feeding operations in terms of their components (e.g., model farms) may be a plausible approach for developing estimates of air emissions from individual farms or regions as long as the components or factors chosen to characterize the feeding operation are appropriate. The method may not be useful for estimating acute health effects, which normally depend on human exposure to some concentration of toxic or infectious substance for short periods of time.

Finding 5. Reasonably accurate estimates of air emissions from AFOs at the individual farm level require defined relationships between air emissions and various factors. Depending on the character of the AFOs in question, these factors may include animal types, nutrient inputs, manure handling practices, output of animal products, management of feeding operations, confinement conditions, physical characteristics of the site, and climate and weather conditions.

Finding 6. The model farm construct as described by EPA (2001a) cannot be supported because of weaknesses in the data needed to implement it.

Finding 7. The model farm construct used by EPA (2001a) cannot be supported for estimating either the annual amounts or the temporal distributions of air emissions on an individual farm, subregional, or regional basis because the way in which it characterizes feeding operations is inadequate.

Finding 8. A process-based model farm approach that incorporates "mass balance" constraints for some of the emitted substances of concern, in conjunction with estimated emission factors for other substances, may be a useful alternative to the model farm construct defined by EPA (2001a).

SOURCE: NRC (2002a).

cause of the differing definitions. The process-based model described in this report is better suited for using a continuous variable (e.g., 500-kg live weight) than a discrete variable (e.g., 1 dairy cow).

FINDING 1. Much confusion exists about the use of the term "animal unit" because EPA and USDA define animal unit differently.

RECOMMENDATION: Both EPA and USDA should agree to define animal unit in terms of animal live weight rather than an arbitrary definition of animal unit.

Spatial Distribution of Effects

The various substances that together make up the total air emissions from animal feeding operations differ in quantity, the potential severity of their effects, and the spatial distribution of these effects. Ammonia, whose environmental impacts are reasonably well understood, has relevant impacts that have to be addressed at regional, national, and global scales. On the other hand, odor, whose composition is not well known in scientific terms and whose impacts on the public are difficult to judge, is important mainly at a very local level.

Table ES-1, which supports and elaborates Finding 2 below, represents the reasoned judgment of the committee on the relative importance of each substance at the relevant spatial scales strictly for emissions from AFOs. For example, volatile organic compounds (VOCs) play an important role in tropospheric ozone formation, yet such emissions from AFOs are likely to be insignificant compared to other sources in most areas.

FINDING 2. Air emissions from animal feeding operations are of varying concern at different spatial scales, as shown in Table ES-1.

RECOMMENDATION: These differing effects, concentrations, and spatial distributions lead to a logical plan of action for establishing research priorities to provide detailed scientific information on the contributions of AFO emissions to potential effects and the subsequent implementation of control measures. USDA and EPA should first focus their efforts on the measurement and control of those emissions of major concern.

Measurement Protocols and Control Technologies

Achieving the overall goal of decreasing the adverse impacts of air emissions from AFOs will require attention to the differences in the character of the various emissions (e.g., their persistence in the atmosphere), in the way they are dis-

TABLE ES-1 Committee's Scientific Evaluation of the Potential Importance[a] of AFO Emissions at Different Spatial Scales

Emissions	Global, National, and Regional	Local—Property Line or Nearest Dwelling	Primary Effects of Concern
NH_3	Major[a]	Minor	Atmospheric deposition, haze
N_2O	Significant	Insignificant	Global climate change
NO_x	Significant	Minor	Haze, atmospheric deposition, smog
CH_4	Significant	Insignificant	Global climate change
VOCs[b]	Insignificant	Minor	Quality of human life
H_2S	Insignificant	Significant	Quality of human life
PM10[c]	Insignificant	Significant	Haze
PM2.5[c]	Insignificant	Significant	Health, haze
Odor	Insignificant	Major	Quality of human life

[a]Relative importance of emissions from AFOs at spatial scales based on committees' informed judgment on known or potential impacts from AFOs. Rank order from high to low importance is major, significant, minor, and insignificant. While AFOs may not play an important role for some of these, emissions from other sources alone or in aggregate may have different rankings. For example VOCs and NO_x play important roles in the formation of tropospheric ozone; however, the role of AFOs is likely to be insignificant compared to other sources.
[b]Volatile organic compounds.
[c]Particulate matter. PM10 and PM2.5 include particles with aerodynamic equivalent diameters up to 10 and 2.5 μm, respectively.

persed, in their environmental effects, and in the effectiveness of various control and management strategies. As noted above, it will also require attention to priorities based on the geographic scale at which impacts are of greatest concern. The local scale is considered the AFO boundary or nearest occupied dwelling. The regional scale may be as small as a single topographic land feature (e.g., a stream valley) or as large as a multistate airshed.

FINDING 3. Measurement protocols, control strategies, and management techniques must be emission and scale specific.

RECOMMENDATIONS:

- **For air emissions important on a global or national scale (i.e., ammonia and the greenhouse gases methane [CH_4] and nitrous oxide [N_2O]), the aim is to control emissions per unit of production (kilograms of food produced) rather than emissions per farm. Where the environmental and health benefits outweigh the costs of mitigation it is important to decrease aggregate emissions. In some geographic regions,**

aggregate emission goals may limit the number of animals produced in those regions.

- **For air emissions important on a local scale (hydrogen sulfide [H_2S], particulate matter [PM], and odor), the aim is to control ambient concentrations at the farm boundary and/or nearest occupied dwelling. Standards applicable to the farm boundary and/or nearest occupied dwelling must be developed.**
- **Monitoring should be conducted to measure concentrations of air pollutants of possible health concern at times when they are likely to be highest and in places where the densities of animals and humans, and typical meteorological conditions, are likely to result in the highest degree of human exposure.**

Current Best Management Plans

As noted in the committee's interim report, available estimates of emission factors, rates, and concentrations are sufficiently uncertain that they provide a poor basis for regulating or managing air emissions from AFOs. Nevertheless, some best management practices to mitigate the adverse effects of air emissions appear at face value to warrant their use, even as new information on mitigation and best management practices is being developed. Although the committee favors a strong focus on research to develop needed new information, the use of clearly effective measures should be encouraged while new information is being developed.

FINDING 4. There is a general paucity of credible scientific information on the effects of mitigation technologies on concentrations, rates, and fates of air emissions from AFOs. However, the implementation of technically and economically feasible management practices (e.g., manure incorporation into soil) designed to decrease emissions should not be delayed.

RECOMMENDATION: Best management practices (BMPs) aimed at mitigating AFO air emissions should continue to be improved and applied as new information is developed on the character, amount, and dispersion of these air emissions, and on their health and environmental effects. A systems analysis should include impacts of a BMP on other parts of the entire system.

Odors

Odors associated with AFO emissions are often regulated in response to nuisance complaints rather than demonstrated health effects. The measurement of

odor concentrations downwind from AFOs is based on olfactometers that relate odor strength to a standard (usually *n*-butanol) or uses the judgment of panels of experts trained to distinguish odor strengths. While standardized terminology and measures have been developed in Europe, a similar effort has not yet occurred in the scientific community in the United States.

Odors continue to be a problem with AFOs at the local level. Continuing research into the constituents of odor with a goal of providing a basis for scientific agreement for standards is needed.

FINDING 5. Standardized methodologies for odor measurement have not been adopted in the United States.

RECOMMENDATIONS:

- **Standardized methodology should be developed in the United States for objective measurement techniques of odors to correspond to subjective human response.**
- **A standardized unit of measurement of odor concentration should be adopted in the United States.**

Dispersion Modeling

FINDING 6. The complexities of various kinds of air emissions and the temporal and spatial scales of their distribution make direct measurement at the individual farm level impractical other than in a research setting. Research into the application of advanced three-dimensional modeling techniques accounting for transport over complex terrain under thermodynamically stable and unstable planetary boundary layer (PBL) conditions offers good possibilities for improving emissions estimates from AFOs.

RECOMMENDATION: EPA should develop and carry out one or more intensive field campaigns to evaluate the extent to which ambient atmospheric concentrations of the various species of interest are consistent with estimated emissions and to understand how transport and chemical dynamics shape the local and regional distribution of these species.

Measurement Protocols

Accurate measurement of air emissions is dependent on the availability and use of protocols that are both technically sound and practical for use in the field, as well as the laboratory. Such measurement protocols are available for measur-

ing nitrous oxide and nitric oxide (NO). Improved measurement protocols are needed for other substances. Particulate matter, odor, and volatile organic compounds are important emissions at the local level, but pose some special problems because their constituents and emission rates vary widely among AFOs and their locations.

FINDING 7. Scientifically sound and practical protocols for measuring air concentrations, emission rates, and fates are needed for the various elements (nitrogen, carbon, sulfur), compounds (e.g., ammonia [NH_3], CH_4, H_2S), and particulate matter.

RECOMMENDATIONS:

- **Reliable and accurate calibration standards should be developed, particularly for ammonia.**
- **Standardized sampling and compositional analysis techniques should be provided for PM, odor, and their individual components.**
- **The accuracy and precision of analytical techniques for ammonia and odor should be determined, including intercomparisons on controlled (i.e., synthetic) and ambient air.**

Emission Factors

The "emission factor" approach for estimating air emissions is based on measuring emissions from a set of defined AFOs to obtain an "average" emission per unit (e.g., per animal unit or per unit of production). These emission factors can then be used to estimate emissions for other AFOs by multiplying the emission factor by the number of observed units to which the average applies. As noted in the committee's interim report, the existing emission factors for AFOs are generally inadequate because of the limited number of measurements on which they are based, as well as the limited generality of the models for which the emission factors have been developed (see Appendix L). Improving existing emission factors to the point where they could provide scientifically credible estimates of either emission rates or concentrations would require major efforts in getting sufficient observations to characterize the variability among and within AFOs.

The committee (in Finding 9 and Chapter 5) suggests that an alternative approach for estimating emissions, a process-based modeling approach, can provide more useful estimates for most of the air emission substances of concern. Particulate matter is the main exception and may require additional efforts to improve emission factors. Allocation of overall resources for improving and evaluating emission estimates should focus on the committee's recommended process-based modeling approach for all emissions mentioned, except for particulate matter.

FINDING 8. Estimating air emissions from AFOs by multiplying the number of animal units by existing emission factors is not appropriate for most substances.

RECOMMENDATION: The science for estimating air emissions from individual AFOs should be strengthened to provide a broadly recognized and acceptable basis for regulations and management programs aimed at mitigating the effects of air emissions.

Process-Based Model

To counter the tendency to consider only on-farm inputs and outputs from AFOs, to ensure more accurate accounting of the flows of chemicals and other air emission substances from the operation, and to provide a "mass balance" control for the total flow of inputs to and outputs from the operation, the committee recommends a "process-based modeling" approach for estimating air emissions.

The process-based modeling approach can be used to estimate the flows of elements (nitrogen, sulfur, carbon) and of compounds containing these elements. The committee believes, with some reservations, that this approach might be used for estimating odor emissions. The only substance of direct concern to the committee for which this approach may not be well suited is particulate matter.

This approach involves the specification of mathematical models that describe the movement of various substances of interest at each major stage of the process of producing livestock products: movement into the next stage, movement in various forms to the environment, and ultimately movement into products used by humans. Mass balance constraints serve as a check on the whole system to ensure that estimates of movements of substances out of the system do not exceed the amounts available within the system.

FINDING 9. Use of process-based modeling will help provide scientifically sound estimates of air emissions from AFOs for use in regulatory and management programs.

RECOMMENDATIONS:

- **EPA and USDA should use process-based mathematical models with mass balance constraints for nitrogen-containing compounds, methane, and hydrogen sulfide to identify, estimate, and guide management changes that decrease emissions for regulatory and management programs.**
- **EPA and USDA should investigate the potential use of a process-based model to estimate mass emissions of odorous compounds and potential management strategies to decrease their impacts.**

- **EPA and USDA should commit resources and adapt current or adopt new programs to fill identified gaps in research to improve mathematical process-based models to increase the accuracy and simplicity of measuring and predicting emissions from AFOs (see short-term and long-term research recommendations).**

Systems Analysis

The emission factor approaches in current use focus on the "on-farm" inputs to and outputs from an AFO. This ignores the potential environmental effects associated with "off-farm" production of feed and other materials used in an AFO. Since some of the feed for typical AFOs is imported from other farms, and a portion of the manure is often exported from the AFO for use on other farms (some regional and species differences exist), restricting consideration of inputs and outputs to a single AFO may not completely represent the full environmental effects of the operation. A "systems approach" that considers both the on-farm and the off-farm inputs and outputs would provide a more accurate description of overall impacts.

FINDING 10. A systems approach, which integrates animal and crop production systems both on and off (imported feeds and exported manure) the AFO, is necessary to evaluate air emissions from the total animal production system.

RECOMMENDATION: Regulatory and management programs to decrease air emissions should be integrated with other environmental (e.g., water quality) and economic considerations to optimize public benefits.

Nitrogen Emissions

Because of its potential environmental impacts at regional, national, and global scales, instituting control strategies for nitrogen emissions should be assigned high priority. Sufficient information is currently available to do this at all geographic scales.

FINDING 11. Nitrogen emissions from AFOs and total animal production systems are substantial and can be quantified and documented on an annual basis. Measurements and estimates of individual nitrogen species components (i.e., NH_3, molecular nitrogen [N_2], N_2O, and NO) should be made in the context of total nitrogen losses.

RECOMMENDATION: Control strategies aimed at decreasing emissions of reactive nitrogen compounds (Nr) from total animal production

systems should be designed and implemented now. These strategies can include both performance standards based on individual farm calculations of nitrogen balance and technology standards to decrease total system emissions of reactive nitrogen compounds by quantifiable amounts.

Research

The two major federal agencies with regulatory or management responsibilities relative to air emissions from AFOs are EPA and USDA. Each of these agencies also has research responsibilities in support of its action programs—responsibilities that are typically serviced through "in-house" research staffs. Close cooperation is needed between the two agencies in setting and supporting research priorities relative to air emissions. Inputs and participation from the full range of state, private, and research institutions with relevant interests are needed to ensure that concerns about air emissions are addressed with the full complement of needed expertise.

The importance of food production from AFOs, coupled with the potential environmental effects from air emissions, demands substantial research efforts in both the short and the long term. These issues will not be resolved without addressing the appropriate funding of these efforts. Current allocations of funding aimed at AFO air emissions are not adequate or appropriate in view of the amount of concern about these emissions and the recent growth in AFO livestock production.

Research in the short term (four to five years) can significantly improve the capability of the process-based modeling approach for estimating air emissions. A long-term (20-30 years) research program that encompasses overall impacts of animal production on the environment, as proposed here, can have even more substantial results in decreasing overall impacts on the environment, while sustaining production at a high level.

FINDING 12. USDA and EPA have not devoted the necessary financial or technical resources to estimate air emissions from AFOs and develop mitigation technologies. The scientific knowledge needed to guide regulatory and management actions requires close cooperation between the major federal agencies (EPA and USDA), the states, industry and environmental interests, and the research community, including universities.

RECOMMENDATIONS:

- **EPA and USDA should cooperate in forming a continuing research coordinating council (1) to develop a national research agenda on issues related to air emissions from AFOs in the context of animal production systems and (2) to provide continuing oversight on the imple-**

mentation of this agenda. This council should include representatives of EPA and USDA, the research community, and other relevant interests. It should have authority to advise on research priorities and funding.

- **Exchanges of personnel among the relevant agencies should be promoted to encourage efficient use of personnel, broadened understanding of the issues, and enhanced cooperation among the agencies.**
- **For the short term, USDA and EPA should initiate and conduct a coordinated research program designed to produce a scientifically sound basis for measuring and estimating air emissions from AFOs on local, regional, and national scales.**
- **For the long term, USDA, EPA, and other relevant organizations should conduct coordinated research to determine which emissions (to water and air) from animal production systems are most harmful to the environment and human health, and to develop technologies that decrease their releases into the environment. The overall research program should include research to optimize inputs to AFOs, optimize recycling of materials, and significantly decrease releases to the environment.**

The reality of budget constraints in allocating research funds to address problems of air emissions requires a careful weighing of several factors, including those that affect both the implementation costs and the societal benefits. Finding 2 proposes a way of ranking both action and research opportunities among the emission substances based on amounts of concern or impacts and geographic scale of impacts. A more complete listing of factors is needed for setting both short- and long-term research priorities and for allocating research funds.

FINDING 13. Setting priorities for both short- and long-term research on estimating air emission rates, concentrations, and dispersion requires weighing the potential severity of adverse impacts, the extent of current scientific knowledge about them, the potential for advancing scientific knowledge, and the potential for developing successful mitigation and control strategies.

RECOMMENDATIONS:

- **Short-term research priorities should improve estimates of emissions from individual AFOs including the effects of different control technologies:**
- **Priority research for emissions important on a local scale should be conducted on odor, PM, and H_2S (also see Finding 2).**
- **Priority research for emissions important on regional, national, and**

global scales should be conducted on ammonia, N_2O, and methane (also see Finding 2).

- **Long-term research priorities should improve understanding of animal production systems and lead to development of new control technologies.**

SUMMARY

These findings and recommendations, taken together, point to two major changes in direction for improving the basic information needed for dealing with the adverse effects of air emissions from AFOs. One is to replace the current emission factor approach for estimating and tracking the rates and fates of air emissions using a process-based modeling approach with mass balance constraints. The second is to initiate a substantial long-term research program on the overall system of producing food from animal feeding operations with the goal of eliminating the release of undesirable air and other emissions into the environment.

Facing the need for defensible information on air emissions from AFOs, in a timely manner, is a major challenge for EPA and USDA. Neither has yet addressed the need for this information in defining high-priority research programs. Each has pursued its regulatory and farm management programs under the assumption that the best currently available information can be used to implement its program goals.

The scope and complexity of the information needed by these agencies, as well as the potential environmental impacts of air emissions from AFOs, require a concentrated, focused, and well-funded research effort. Such an effort is described in this report.

EMISSIONS

From Animal Feeding Operations

Current Knowledge, Future Needs

Ad Hoc Committee on Air Emissions from Animal Feeding Operations
Committee on Animal Nutrition
Board on Agriculture and Natural Resources
Board on Environmental Studies and Toxicology
Division on Earth and Life Studies

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The committee is grateful to members of the National Research Council staff who worked diligently to maintain progress and quality in its work.

The report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

David T. Allen, The University of Texas, Austin, Texas
William Battye, EC/R Incorporated, Chapel Hill, North Carolina
Van C. Bowersox, Illinois State Water Survey, Champaign, Illinois
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Wendy J. Powers, Iowa State University, Ames, Iowa
Joseph Rudek, Environmental Defense, Raleigh, North Carolina
Margot Rudstrom, University of Minnesota, Morris, Minnesota

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Bob Frosch, Harvard University, Cambridge, Massachusetts, and Albert Heber, Purdue University, West Lafayette, Indiana. Appointed by the National Research Council, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

The increasing concentration of food production—meat, eggs, milk—from animals in very large feeding operations has focused public attention on associated environmental issues. These include the effects of air emissions, especially those that come from the large quantities of manure produced by the animals. While concern has mounted, research to provide the basic information needed for effective regulation and management of these emissions has languished.

This report, prepared by a committee appointed by the National Research Council, proposes two major ways to improve information and the nation's ability to deal with the effects of these emissions. One is to change the way in which the rates and fate of air emissions are estimated and tracked. The proposal would replace the current "emission factor" approach with a "process-based modeling" approach. This can, if pursued vigorously, enhance both regulation and management of air emissions in the next two to five years.

The other proposal is for a research program that views air emissions as one part of the overall system of producing food from animal feeding operations with the goal of eliminating the release of unwanted emissions into the environment. This "systems-based" proposal, if also pursued vigorously, would lead to fundamentally changed practices at animal feeding operations. The net result would be continued food production with greatly reduced adverse environmental effects.

The 16-person committee that produced this report and an earlier interim report worked hard and well. The time allowed for producing the two reports was short, but committee members found time in their schedules to address what each sees as an important issue that needs attention. The project staff at the Board on Agriculture and Natural Resources, Jamie Jonker, study director, and Tanja Pilzak, research assistant, and the Board on Environmental Studies and Toxicol-

ogy, Chad Tolman, program officer, deserve special thanks for their long hours of very effective work. An informal editorial subcommittee that handled reviewer comments and provided enormous help throughout also deserves special thanks. The members were Chair Perry Hagenstein, Vice Chair Bob Flocchini, Jim Galloway, Rick Kohn, and, for the interim report, Wayne Robarge.

Perry Hagenstein, *Chair*
Robert Flocchini, *Vice Chair*
Committee on Air Emissions from
Animal Feeding Operations

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