Agricultural Air Quality Perspectives

Overview of the National Air Emissions Monitoring Study (NAEMS)

John Thorne
Agricultural Air Research Council (AARC), Washington, DC 20004, USA.

Abstract

Under the terms of EPA's animal feeding operations consent agreement (FR 70, 19, 4958-4977, Jan 31, 2005), agriculture is to fund and produce a national air emissions monitoring study to generate data that will characterize air emissions from all major types of animal feeding operations ("AFOs") in all significant geographic areas for each participating industry. The Agricultural Air Research Council (AARC) is a tax-free, non-profit industry organization set up to produce the study and administer the funds. EPA will supervise the study, analyze the monitoring results, and aggregate it with appropriate existing emissions data to create tools (e.g., tables and/or emissions models) that AFOs and regulators could use to determine whether they emit pollutants at levels that require them to apply for permits under the Clean Air Act or submit notifications under CERCLA or EPCRA. The swine, dairy, egg laying and broiler chicken industries have chosen to participate and have pledged funds totaling more than $15 million for the two-year study. A large team of government and university scientists and private sector experts worked for two years to select the instrumentation, protocols and quality assurance/quality control methods to be used across locations and animal species. In addition, there has been extensive internal review and input by representatives from the US EPA's Office of Enforcement and Compliance Assurance, Office of Air and Radiation, and Office of Research and Development. As recommended in the National Academy of Science 2003 report, "Air Emissions From Animal Feeding Operations," measurements also will be made during the NAEMS study to initiate a process-based consideration of the entire animal production process and its effects on air emissions. This will include continuous measurements of animal age and weight gain throughout the study; diurnal animal activity levels; manure management/handling practices; animal feeding schedules; lighting, heating and cooling schedules; fan operation; floor and manure temperatures; inside and outside air temperatures and humidity; wind speed and direction; solar radiation; feed and water consumption; manure production and removal schedules; swine mortalities; animal production schedules; and analyses for total nitrogen and sulfur in feed, water, and manure. These NAEMS observations, plus those of parallel studies funded by the dairy and swine industries will lay the groundwork for developing the more process-related emissions models recommended by the NAS. There will be an immense increase in scientific knowledge generated from the NAEMS, and experts involved are convinced that significantly increasing the number of farms to be monitored would be prohibitively expensive and would not add substantially to the value of the data collected. As EPA completes its use of the NAEMS data, participating scientists and universities will be free to publish what is likely to be a large number of scientific journal articles from the air emissions and process-based observations collected during this study, as well as papers on the methods used and models tested. The equipment purchased for the study will be made available through AARC members for other studies following the NAEMS.

Agricultural Air Quality at NRCS

Margaret Walsh, Greg Johnson, Ron Heavner, Roel Vining, Greg Zwicke and Susan O'Neill
Natural Resources Conservation Service
U.S. Department of Agriculture

Overview

Since 1935, the Natural Resources Conservation Service (NRCS, originally the Soil Conservation Service) of the U.S. Department of Agriculture (USDA) has worked with America's private land owners and managers to conserve soil, water, and other natural resources. More recent emphasis on atmospheric resources has expanded the Agency's and the USDA's activities in this area. This emphasis is due in part to the following:

- a heightened awareness of agriculture's role in air quality,
- the need for improving the sustainability of agriculture through conservation and preservation of air quality and atmospheric resources,
- the management of the growing agriculture/urban interface,
- the need for the development of market-based incentives in environmental and conservation programs, and
- the air quality regulatory impacts felt by producers.

In response to NRCS's increasing role, and a need to clarify this role, we are continuing to develop Department-wide national atmospheric resource policy in collaboration with our colleagues at the Agricultural Research Service, the U.S. Forest Service, CSREES, and the Economic Research Service of the USDA.

Of the 79 resource concerns identified for conservation planning prioritization in the NRCS, 12 are in air resources. Agricultural emissions of criteria pollutants and other pollutants of concern tend to be more diffuse and variable than those from other industries; therefore, the means for reduction requires a unique set of approaches. Atmospheric resource considerations include three greenhouse gases (GHGs) which have agricultural connections—carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). NRCS seeks to develop and help implement relevant agricultural air quality technologies and practices, while enabling producers to apply them to the environmental, societal, financial, and technical benefit of all parties. With field staff in almost every county in the U.S., NRCS employees provide technical assistance based on sound science and suited to a customer's specific needs. NRCS provides financial assistance for many of its voluntary conservation activities.

Research provides a fundamental basis for any potential reductions in agricultural atmospheric emissions. However, interpretation and incorporation of those discoveries into working practice is necessary for realizing that potential. The NRCS applies a cooperative approach, providing land owners and managers with the expertise, information, tools, and financial support to evaluate and implement responsible land management decisions, while incorporating local experience from partners and program participants.

NRCS scientists are reviewing and updating accepted conservation practices and other activities which can address air quality and atmospheric change issues for agriculture. These practices and activities are delivered to producer-cooperators through conservation planning assistance, and through specific financial and conservation assistance programs.

Agricultural Air Quality and Atmospheric Change Focus Areas

Six broad air resource issues have been identified as being of greatest importance at the present time to agriculture, in general, and for special emphasis in the NRCS:

- Particulate Matter (both coarse, between 2.5 and 10 micrometers in diameter, and fine, less than 2.5 micrometers in diameter)
- Ozone (O_3) precursors, most notably nitrogen oxides (NO_x) and volatile organic compounds (VOCs)
- Greenhouse gases (CO_2, N_2O, and CH_4)
- Ammonia (NH_3)
- Odors
- Chemical drift (primarily of pesticides and herbicides)

The following examines specific activities and practices encouraged by the NRCS to address each of these issues.

Particulate Matter

Specific activities in the NRCS to reduce particulate matter (PM) emissions have been heavily focused on coarse particles, but with increasing emphasis on fine particulates, due primarily to the increasing body of research evidence showing the greatest issues associated with fine PM. Many research studies indicate that traditional agricultural activities such as tillage and other field operations generate a greater proportion of coarse rather than fine particulates, though greater investigation of the role of agricultural emissions in primarily, as well as secondarily, emitting $PM_{2.5}$ is just now being pursued in earnest.

Some examples of NRCS activities in reducing PM emissions include:

- Wind erosion estimation and control. The Wind Erosion Prediction System (WEPS) model, being developed by the USDA Agricultural Research Service (ARS), is used to predict particulate matter emissions and transport from wind erosion based on local conditions, environment, and management. WEPS includes consideration of field-scale variability, topography, and field geometry when making wind erosion estimates.
- Smoke management of prescribed burning. The NRCS works with state and local agencies to adopt and implement Smoke Management Programs (SMPs) designed to allow the use of fire as an accepted management practice, while protecting public health and welfare by mitigating impacts on resources of concern. The NRCS is also updating the prescribed burning practice standard to include smoke screening procedures effective at mitigating smoke impacts and is also partnering with other federal agencies (such as the Forest Service) to access smoke management tools (such as BlueSkyRAINS) that can be applied to agricultural smoke issues.
- Residue management, cover crops, wind barriers, implementation of a prescribed burning management plan, and alternate slash disposal methods represent a few sanctioned practices which may be applied to reducing a farm's particulate matter emissions.

Ozone Precursors

- Reducing the formation of tropospheric ozone through managing emissions of its direct precursors, including volatile organic compounds (VOCs) and nitrogen oxides (NO_x). Integrated pest management and comprehensive nutrient management planning for VOC emission reductions, and minimizing fuel combustion via reduced tractor operation (from implementing conservation tillage measures) or replacing fossil-fuel fired irrigation engines with electric motors for NO_x are examples of effective measures taken by producers to address ozone precursors.

Greenhouse Gases

There are three greenhouse gases of interest to American agriculture and NRCS: carbon dioxide (CO_2, from soil tillage, burning, and vehicle emissions), nitrous oxide (N_2O, from soil applied nutrients), and methane (CH_4, from animal production and waste management). Agricultural practices can help to lower atmospheric concentrations of these gases by:

- Sequestering carbon in soils by reducing soil tillage and disturbance

- Managing nitrogen fertilization to minimize N_2O emissions from the soil to the air
- Managing animal feeding and manures to minimize CH_4 release from production facilities.

Ammonia

Ammonia emissions (and consequent formation of fine particulate matter) may be reduced through

- Specific activities—such as splitting fertilizer applications through time or injecting fertilizers, as well as instituting an approved feed management system—demonstrate reduced ammonia emissions from agricultural operations.
- Trees that thrive on ammonia rich environments have been found to be useful in tree breaks in front of exhaust fans because they mitigate ammonia movement off-site.

Odors

- Odors from animal production and waste management, utilization, and disposal may be mitigated by activities, such as feed management and proper manure handling, storage, and processing.
- Trees may be used as windbreaks to reduce odors from animal production facilities, filtering mechanisms may be fitted onto animal buildings, or waste injection may be used, to list a few examples of effective agricultural odor emission reduction practices.

Chemical Drift of Pesticides and Herbicides

- Effective methods of reducing chemical drift from agricultural operations include the use of tree windbreaks to reduce chemical drift from fields, use of proven adjuvants to reduce overall application levels, and sensitivity to local meteorological conditions that impact volatilization characteristics.

NRCS Technical Documents

The basis for NRCS conservation practices and activities has always been based upon sound science gleaned from documented and well-respected research. Several technical document pathways exist in the Agency, establishing for NRCS personnel, as well as for the general public, the procedures that should be followed for conservation planning. With regard to air quality and atmospheric change which are relatively new areas of focus for the NRCS, new technical guidance is just now being developed and integrated into Agency procedures. These include;

The electronic Field Office Technical Guide (e-FOTG) is the primary scientific reference for NRCS, and is available online through NRCS's website. Guides are tailored to specific geographic areas, and contain technical information about the conservation of soil, water, air, and related plant and animal resources for those areas. The e-FOTG contains numerous categories of information useful for land managers and NRCS advisors, including:

- Site specifications, including NRCS Soil Surveys, Hydric Soils Interpretations, Ecological Site Descriptions, Forage Suitability Groups, Cropland Production Tables, Wildlife Habitat Evaluation Guides, Water Quality Guides, and other related information.
- NRCS Quality Criteria, which establish standards for resource conditions that help provide sustained use.
- NRCS Conservation Practices and Conservation Specifications, which define useful conservation practices and their installation requirements. The effect different practices may have on resources of concern is described by the e-FOTG.

National Engineering Handbook chapters dealing with specific agricultural air quality issues are being developed. The first chapters in final review will provide information on Odors, Tropospheric Ozone, and Greenhouse Gases. These chapters will provide NRCS personnel with a concise, scientific overview of each subject, along with recommended conservation procedures that will help address each of these issues.

NRCS is currently updating, and preparing in some cases, the air quality sections of the National Environmental Compliance Handbook. This handbook provides guidance to NRCS personnel about how to comply with federal environmental requirements when delivering technical and financial assistance.

A review of existing NRCS National Conservation Practice Standards and Conservation Practices Physical Effects (CPPE) has also begun in order to incorporate relevant and current information on agricultural air quality and atmospheric change issues. NRCS Practice Standards are technology or practice-specific documents that contain information on why and where the practice is applied, and sets forth the minimum quality criteria that must be met during the application of that practice in order for it to achieve its intended purpose(s). The CPPE documents provide guidance on how the application of that practice will affect the resources (soil, water, air, plants, animals and human) and the resource concerns associated with each of those resources. NRCS is also working to quantify the anticipated atmospheric improvement resulting from conservation efforts, including those from specific practices.

NRCS Agricultural Air Quality Tools

NRCS currently provides two tools to land managers and their advisors which maximize the conservation benefits of their practices. The tools are affixed with user-friendly interfaces, allowing many kinds of people access. NRCS is also reviewing opportunities to develop other tools that address air quality resource concerns.

The Wind Erosion Protection System (WEPS) is a process-based, continuous modeling system that employs site-specific soil, climate, wind, and other environmental conditions to predict wind erosion and the utility of practice standards for a given site.

The **V**oluntary **R**eporting of Greenhouse Gases-**C**arb**O**n **M**anagement **E**valuation **T**ool (**COMET-VR**) is a decision support tool for agricultural producers, land managers, soil scientists and other agricultural interests. Users of COMET-VR specify a history of agricultural management practices on one or more parcels of land. The results are presented as ten year averages of soil carbon sequestration or emissions with associated statistical uncertainty values. Estimates can be used to construct a soil carbon inventory for the Department of Energy's voluntary 1605(b) program.

NRCS Programs

NRCS operates a number of conservation programs that provide land owners and managers with technical and financial assistance on private lands to assist with the implementation and demonstration of developed and new conservation practices. The main programs that address agricultural air quality are the Environmental Quality Incentives Program (EQIP), which includes the Conservation Innovation Grant (CIG) program, and the Conservation Security Program (CSP).

Environmental Quality Incentives Program

EQIP provides a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial (cost-share of up to 75 percent of the costs of certain conservation practices) and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land. In 2005, NRCS awarded $31 million in EQIP contracts that listed air quality as either a primary or secondary concern.

EQIP activities are carried out according to an environmental quality incentives program plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice or practices to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions, and the local conservation district approves the plan.

Conservation Innovation Grants

The CIG program is authorized under EQIP as a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging Federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, EQIP funds are used to award competitive grants to non-Federal governmental or non-governmental organizations, Tribes, or individuals. CIG enables NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the Nation's most pressing natural resource concerns.

NRCS awarded $1.6 million in 2005 for five CIG air quality projects. An additional eight awarded CIG projects address air quality as a secondary concern.

Conservation Security Program

CSP is a voluntary program that that supports ongoing stewardship of private agricultural lands by providing payments for maintaining and enhancing natural resources. CSP provides financial and technical assistance to promote the conservation and improvement of soil, water, air, energy, plant and animal life, and other conservation purposes on Tribal and private working lands. CSP identifies and rewards those farmers and ranchers who are meeting the highest standards of conservation and environmental management on their operations. In fact, the CSP motto is to "reward the best and motivate the rest."

NRCS has developed over 35 job sheets and worksheets to address the six principal air quality issues mentioned previously in this paper. These documents outline the different air quality enhancements that are eligible for payment under CSP, such as conservation tillage, windbreaks, and management of prescribed burning to address particulate matter issues and manure fertilizer injection and feed and manure management to address odor issues.

The USDA Agricultural Air Quality Task Force

The Chief of NRCS is the Chairman of the Agricultural Air Quality Task Force (AAQTF), a Federal Advisory Committee composed of individuals representing a diverse range of expertise. Recent advice to USDA as a result of this group has included:

- research priorities,
- policy on voluntary market-based incentive programs,
- agricultural burning,
- atmospheric emissions and impacts from agricultural operations, and
- other air quality related regulatory issues.

Summary

The mission of the NRCS is to provide leadership in a partnership effort to help people conserve, maintain, and improve our natural resources and environment. As such, we share a commitment to the conservation and preservation of air quality and atmospheric resources, especially as it relates to agriculture. We will continue to assist land owners and managers with technical and financial assistance on private lands to accomplish this goal and to identify, develop, promote, and implement agricultural practices and technologies that help people help the land.

For more and updated information on NRCS agricultural air quality activities, including links to the AAQTF web site, and specific programmatic information, please visit: http://www.airquality.nrcs.usda.gov/

Use of Collaborative Partnerships to Address Environmental Impacts of Agriculture

Richard Sprott[1], Bryce Bird[2], George Hopkin,[3] and Mark Peterson[4]
[1]Director, Divison of Air Quality, Utah Department of Environmental Quality, Salt Lake City, Utah
[2]Manager, Air Standards Branch, Divison of Air Quality, Utah Department of Environmental Quality, Salt Lake City, Utah
[3]Environmental Practices Manager, Utah Department of Agriculture and Food, Salt Lake City, Utah
[4]Water Quality Specialist, Utah Farm Bureau Federation, Sandy, Utah

Abstract

Environmental management in the United Stated has become an increasingly polarized process. Our decision-making is typically founded on principles of science, policy and law. Each circumstance can lead to one or more of the three disciplines dominating the others. As this occurs, the process can fracture. This is especially true if a dispute arises and the matter is "decided" by a court. The legal process creates winners and losers and often simply kicks the matter back to the same parties for solution. In contrast, collaborative processes can often provide more effective and lasting environmental results since the would-be adversaries become jointly responsible for solutions. A variety of successful partnerships have been implemented in the West in recent years. The Western Regional Air Partnership built strategies that have significantly reduced regional sulfur dioxide emissions that create haze in national parks. In March 2001, the Utah Concentrated Animal Feeding Operation (CAFO) Committee finalized a strategy to rapidly assess and mitigate impairment of water bodies by CAFOs due to non-point source water pollution. The Committee was a partnership comprised of the Utah Department of Environmental Quality, Utah Department of Agriculture and Food, Utah Farm Bureau, Utah Association of Conservation Districts, and various grower groups. The strategy was noteworthy for its innovative use of all partners to deal with the problem instead of the traditional practice of regulators writing permits, inspecting farms, and issuing violations for noncompliance. The results were stunning. Assessments were accomplished and permits issued much faster than other state programs. More importantly, farmers implemented best management practices (BMP) promptly with nitrogen, phosphorous, and BOD loadings reduced 95% by 2005. A similar partnership has now been formed to assess and mitigate agricultural air emissions in Utah. Most Utah farmers did not feel the proposed USEPA national monitoring settlement was useful to them. It was costly and would not yield data relevant to arid agricultural practices in the intermountain West. The AFO Committee created an air strategy that was formalized through a Memorandum of Understanding with USEPA Region VIII in August 2005. The MOU contains commitments for timely monitoring using approved protocols and quality procedures. A major focus of the Utah program is evaluation of BMPs so solutions can be accelerated and multimedia impacts evaluated. The Utah partnership stands in sharp contrast to the far more contentious national effort that has limited emphasis on BMPs and cross-media impacts.

Introduction

Agriculture, especially CAFOs, have come under increased scrutiny in recent years as sources of air pollution and the United States Environmental Protection Agency (USEPA) and state regulatory agencies are taking steps to evaluate the air quality impact of these activities. The USEPA initiated a national CAFO emissions inventory program using a consent decree process through the agency's Office of Enforcement and Compliance Assurance (OECA) (Federal Register, 2005a). The approach has been criticized as being too lax by some states and environmentalists and too heavy-handed by farm interests. Such polarized outcomes have become increasing common in air quality management and can stymie timely and effective results on the ground. Solutions that rely on greater collaboration and outcome responsibility by all stakeholders can be more effective than the traditional command-and-control and litigation-centric system of the last 30 years. This paper examines some principles for successful collaboration in environmental policy-making and describes examples where the principles have been successfully applied in the western United States.

Methods

Environmental Policy Making through Collaboration

The approach described here (Nielson, 2004) is based on the environmental policy-making principle of "Science for Facts, Process for Priorities" of the *Enlibra Principles* adopted by the Western Governors' Association (WGA, 1998) and the National Governors' Association (NGA, 2000). One may view environmental management as a graphical representation of an equilateral triangle with the vortices being Science, Law, and Policy (Figure 1). When applied in balance, the three forces can provide effective protection of natural resources. If one or more of the forces is used to dominate the others, the imbalance fractures our ability to effectively manage environmental protection. Different management activities require appropriate use of only parts of the triangle.

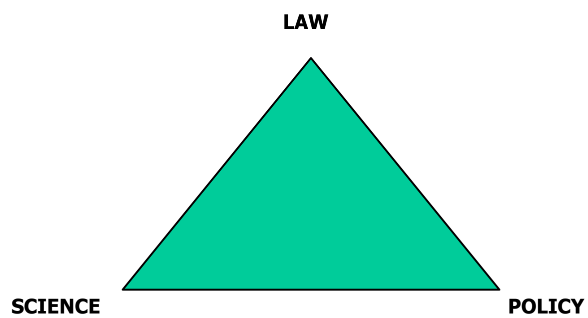

Figure 1. Environmental Policy-Making
(based on the Principle of Science for Facts, Process for Priorities)

Standard setting involves interplay between Science and Policy with Science forming the basis for the decisions (Figure 2).

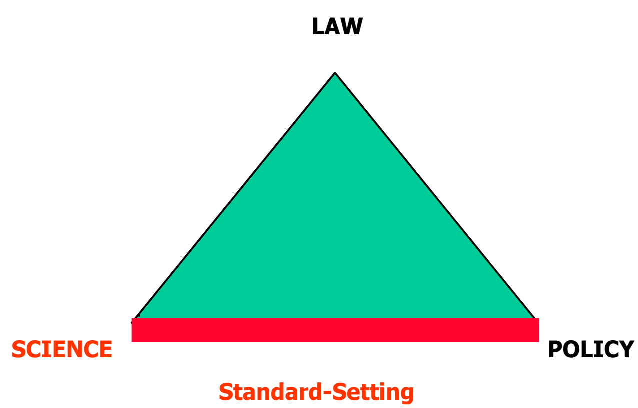

Figure 2. Environmental Policy-Making, Standard Setting

An ideal situation is represented in Figure 3 that portrays dose-response data for substances A and B. Analytical methods exist to detect even minute concentration of both compounds. Compound A has no lower limit of health effects or no no-observable-effects-level (NOEL). Compound B does have a NOEL as seen with the flat curve for health impacts at low concentrations. Science would inform us that there is not safe level of compound A and that there is some safe concentration of compound B that can be tolerated without health impacts.

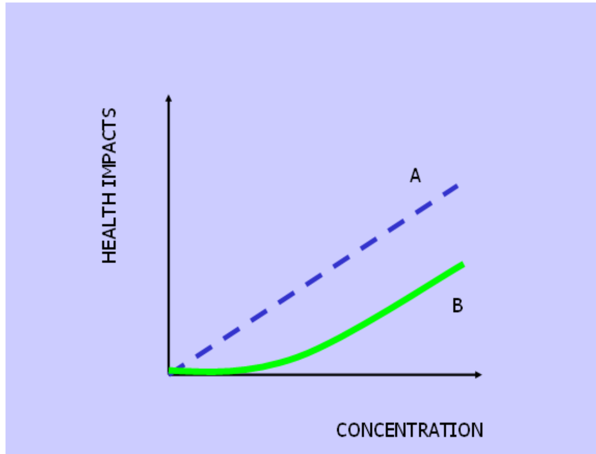

Figure 3. Standard Setting, Science Only

Sometimes the standard will be informed by Policy (Figure 4). If the pollutant has a detection limit, science may not be able to find a NOEL concentration for Compound A. An informed policy decision may determine that the standard should be at some concentration above zero pending more research or better analytical equipment.

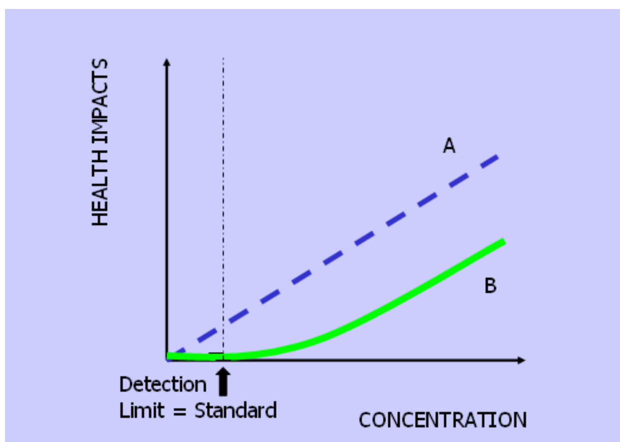

Figure 4. Standard Setting, Science and Policy

Rulemaking is a balance of Science and Law (Figure 5).

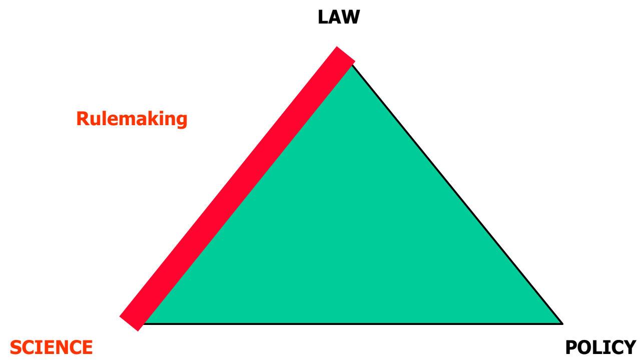

Figure 5. Environmental Policy-Making, Rule Making

A recent example of this process is the Clean Air Act requirement for USEPA to reduce hazardous air pollutants from fossil-fueled power plants (United States Code 1990a). Power plants are a significant source of air pollution (Figure 6). In 2000, the power sector generated 63% of sulfur dioxide and 22% of oxides of nitrogen in the United States (USEPA 2003 and Chu et al 2001). In 1999, power plants were responsible for an estimated 40% of 78 tons of mercury emissions that year.

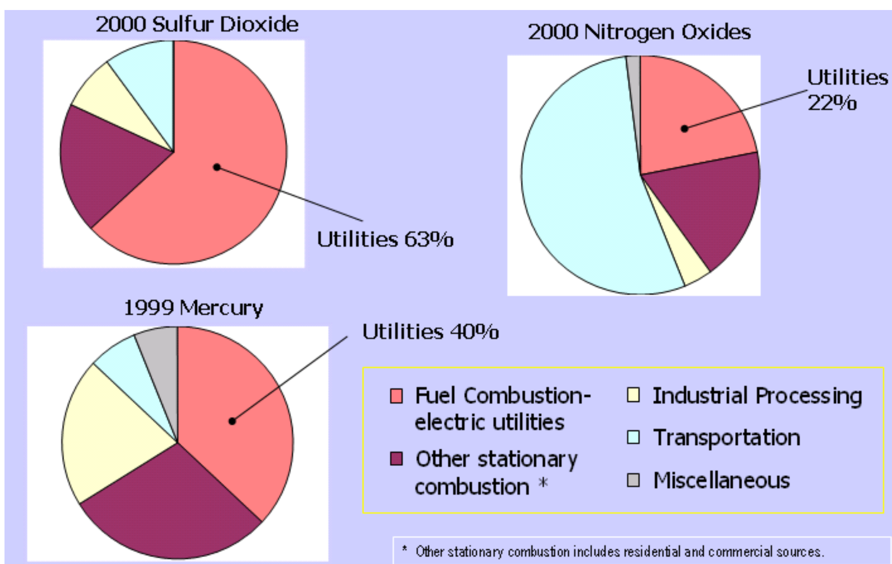

Figure 6. Coal-fired Power Plant Emissions

Mercury chemistry and control technology are complex and limited data was available as the agency sought to promulgate a rule. A stakeholder workgroup was chartered under the auspices of the Clean Air Act Advisory Committee (CAAAC). The workgroup was unable to report back with complete consensus, but it did provide a range of recommendations for a maximum achievable control technology (MACT) rule that reflected the significant uncertainty of the science as well as the control equipment engineering and economics. (Amar 2002) The outcome of this process will be examined further below.

Planning is a crucial function of environmental management and the disciplines of Law and Policy dominate this process (Figure 7).

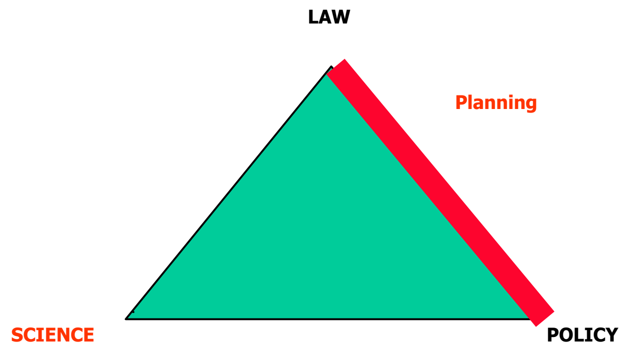

Figure 7. Environmental Policy-Making, Planning

Transportation planning provides a good example of traditional approaches. The federal statues and rules that set forth the process for transportation planning create a complex system of steps for states and metropolitan planning organizations (MPOs) that leads to a long range transportation plan with a 20-year horizon and a state transportation implementation plan with a shorter horizon for funding and design of specific projects (Code of Federal Regulations 2001). The process looks at the present and sets forth a single plan for the future, one forecast – one solution. The process can constrain outcomes.

The current model for environmental policy-making and problem solving is defined by a number of characteristics, almost all negative. Starting points for stakeholders are often defined as *extremes*. Participants use emotional symbols. Processes become *weapons*, not *tools*. Lawyers, lobbyists, dueling scientists and public relations firms become "proxy stakeholders" hired by the real interested parties. The result can be years of costly and divisive conflict. Even worse is the lack of real environmental progress as the drama unfolds.

A recent example introduced above is the mercury rule for power plants. The USEPA finally promulgated a mercury rule in 2005 (Federal Register 2005b) that disregarded the CAAAC's report and infuriated many stakeholders (Becker 2005). Not surprisingly, the agency was sued by multiple parties (USEPA 2005). The case is pending before the US Court of Appeals for the District of Columbia. This course of events has become the norm and might be represented graphically by a 3-D figure in which the triangle has grown vertically with the Courts now at the pinnacle and responsible for the outcome (Figure 8).

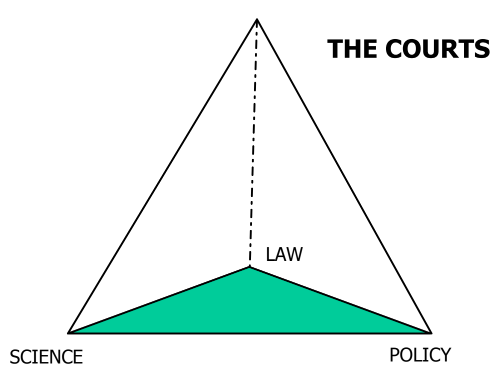

Figure 8. Environmental Policy-Making, Courts Decide

Ironically, the Court regularly throws the controversy back to the same protagonists for resolution through remands (Federal Register 2004). Even if a court's opinion is "decisive" and a rule is vacated, the original parties often just get to start all over to solve the problem.

A more productive approach uses the same three elements of Science, Law, and Policy in a more balanced and respectful manner in a stakeholder process (Nielson, 2004) under the *Enlibra* principle of "Science for Facts, Process for Priorities." This is a process that allows (even requires) stakeholders to take responsibility for solutions, not just their position (Figure 9). Under this approach, participants separate subjective choices from objective data gathering. The group must also avoid polarized positions backed by selective scientific "facts" that do not allow for environmental problem solving. A key component discussed further below is incorporating Science into the Policy-making process. Finally, communicate, communicate, communicate. Stakeholders need to agree to and take responsibility for these principles as a condition of participation.

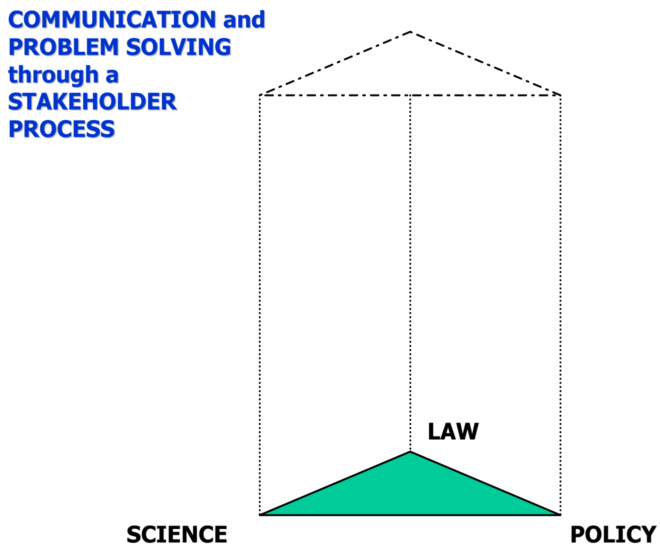

Figure 9. Environmental Policy-Making, Shared Responsibility for Outcomes

The method of incorporating Science into the Policy-making process warrants further examination. First, the process needs to include a *range* of respected scientists who are independent of pre-existing stakeholder positions. A peer review of scientific findings should be undertaken to the maximum extent possible to ensure that *all* issues are addressed appropriately. The group must make decisions based on the best information available; uncertainty can rarely, if ever, be eliminated. The public must be educated about the science used to build credibility and acceptance of any decisions that are eventually made. Once decisions are made, the group has to monitor the outcomes to ensure the desired results or modify the course of action appropriately.

Collaborative processes may not be appropriate or successful in all settings, but partnerships have provided solutions for surprisingly contentious situations. Examples are described below as well as a collaborative strategy for addressing air quality impacts from agriculture.

Results and Discussion

Regional Haze and the Western Regional Air Partnership (WRAP)

Regional haze in the West is an example where collaboration was used to achieve at effective rulemaking. The 1990 amendments to the Clean Air Act established a requirement to reduce regional haze on the Colorado River Plateau and the Grand Canyon Visibility Transport Commission (GCVTC) was established to determine solutions (United States Code 1990b). The Commission issued its consensus report in June 1996 (Grand Canyon Visibility Transport Commission. 1996). Crucial to this effort was the Commission's Public Advisory Group comprised of a diverse set of stakeholders representing states, tribes, federal agencies, local government, academia, media, industry, and public interest groups. It was this group that hammered out consensus for the report. Ironically, the USEPA omitted the GCVTC's recommendations from the proposed regional haze rule (Federal Register 1997). The strength and value of consensus among a large and diverse stakeholder group quickly convinced the agency to embrace the Commission's report. The USEPA adopted the recommendations in section 309 in its final regional haze rulemaking (Federal Register 1999).

The Western Regional Air Partnership (WRAP) was formed from many of the same stakeholders to develop implementation strategies for the rule. The work of the GCVTC and WRAP provided a suite of flexible alternatives to the more traditional regulatory approach of section 308 of the haze rule. The keystone provision was a backstop sulfur dioxide trading program for major sources of sulfur dioxide. Regional annual emission milestones were established for all major sulfur dioxide sources, not just coal-fired power plants. This program and others would achieve significant reductions of pollution causing haze in western Class I national parks and monuments while providing great flexibility to industry and regulating authorities. Extraordinary effort was made to recognize the undeniable role coal would play in future electrical generation while reducing emissions. Five states (Arizona, New Mexico, Oregon, Utah, and Wyoming) submitted state implementation plans under section 309 by December 2003. Despite the enormous effort to gain consensus, the section 309 rules were repeatedly litigated by the Center for Energy and Economic Development (CEED) and others; various parts of the rule were subsequently vacated or remanded to the USEPA (American Corn Growers vs. EPA 2002, Center for Energy and Economic Development vs. EPA 2005). Remarkably, most stakeholders, including regulated industry, remain committed to the strategy conceived by the GCVTC. Sulfur dioxide from coal-fired power plants was reduced by 202,500 tons per year or 35 percent by 2004, already ahead of the required milestones. Reductions by 2018, the end of the first planning period, are expected to be 325,000 tons or 60 percent (Cummins 2005). The GCVTC recommended a 50-70% reduction of sulfur dioxide from all major sources from 1990 levels by the year 2040. Considering all major sulfur dioxide sources (power plants, smelters, refineries, cement plants, etc.), there has already been a 40 percent reduction from 829,000 tons to 501,000 tons in 2004. While legal battles and their fallout create uncertainty, air quality progress continues, not because of rules, laws, or threats of enforcement, but because of the power of the collaborative partnership has been sustained.

Envision Utah and Transportation Planning

As discussed above, environmental planning often involves the law and policy, but traditional methods can result in only one outcome that may not be acceptable to all parties. The Legacy Highway in Utah is such an example. In 1996, the Wasatch Front Regional Council and Utah Department of Transportation expedited planning for a new freeway connecting Salt Lake County to Davis County to the north to relieve rush hour congestion and provide an alternative to Interstate Highway 15 as the only major north-south highway in that corridor. The proposal was very popular with Davis County residents and appeared headed for quick funding and construction. However, there were others who felt the project promoted urban sprawl, threatened wetlands, and would damage air quality. They argued that all corridor and mass transit alternatives were not considered in the environmental impact statement. These parties ultimately were granted an injunction halting construction in November 2001 from the 10th US Circuit Court of Appeals just as the project got underway. In late 2005, the parties and the State sealed an agreement that would allow construction of a more modest roadway with less environmental impact. Construction is scheduled to resume in March 2006 (West, 2006). The delay cost Utah taxpayers an estimated $220 million (Buttars, 2005). Further, there has been a strong backlash against the Sierra Club, Salt Lake City Mayor Rocky Anderson and others who participated in the legal action in the form of emotional statements in the media, various retaliatory tax proposals (Ewing, 2002) and proposed legislation to require expensive bonds before a stay could be requested (Tilton 2006). The result of poor initial collaboration by meeting only the minimum consultations required by law proved both costly and divisive.

By contrast, Envision Utah, a public-private partnership formed to seek alternative visions for Utah's future, undertook the largest public outreach program in the history of Utah. The concept was simple: Ask Utahns what they want their communities to look like many years into the future by providing a choice of outcomes. The effort first sought input of what issues mattered. It then convened hundreds of focus groups with maps and markers to actually draw out preferred alternatives. Finally, a set of four alternatives were presented through thousands of newspaper inserts and the internet to allow people to "vote" on major decisions for transportation, water, housing, air quality, and other matters. The alternatives were displayed graphically and with costs so it was easy to understand the choices. The results have been widely portrayed and used by a wide array of municipal, regional, and state officials, business leaders, and the public ever since.

A further outgrowth of Envision Utah and the failure of the Legacy Highway process has been a very different approach to transportation planning along the Wasatch Front. The Wasatch Front Regional Council and Mountainlands Association of Governments united to work with Envision Utah to develop a new vision that embraced more views and a broader geographic area (Wasatch Front Regional Council 2005). Utah Department of Transportation, the Utah Transit Authority, the metropolitan planning organizations, state and federal environmental and natural resources agencies have also formed an Executive Planning Team. These same groups have invited public interest groups to chart the course for future transportation infrastructure. The result is that planning a new major beltway and significant transit projects are progressing without the highly charged atmosphere that accompanied the Legacy Highway.

Utah Strategy for Water Pollution from Animal Feeding Operations

In 1999, the United States Department of Agriculture (USDA) and the USEPA released a joint unified strategy to address runoff from animal feeding operations (AFO) which allowed for a certain amount of flexibility in detail by individual states. Following the release of the national strategy, the Utah Department of Environmental Quality (UDEQ), Division of Water Quality (DWQ) organized the Utah AFO Committee to develop a workable strategy for Utah. In March 2001, the Utah AFO Committee finalized a strategy to rapidly assess and mitigate impairment of water bodies by CAFOs due to non-point source water pollution (Utah AFO Committee 2001). The Committee was a partnership comprised of the Utah Department of Environmental Quality, Utah Department of Agriculture and Food, EPA, USDA Natural Resources Conservation Service (NRCS), Utah State University Extension Service, Utah Farm Bureau Federation, Utah Association of Conservation Districts, and various grower groups. The strategy was noteworthy for its innovative use of all partners to deal with the problem instead of the traditional practice of regulators writing permits, inspecting farms, and issuing violations for noncompliance. A schematic of the process is shown in Figure 10.

The partnership approach allowed the producers to work closely with organizations with which they had an established relationship of trust. The knowledgeable committee members were able to provide information about animal waste management designs that were affordable and proven to be effective in preventing runoff into the waters of the State. The committee developed training materials and provided 19 manure management workshops throughout the state and 10 workshops to develop and write Comprehensive Nutrient Management Plans (CNMPs) (Loveless et al., 2004).

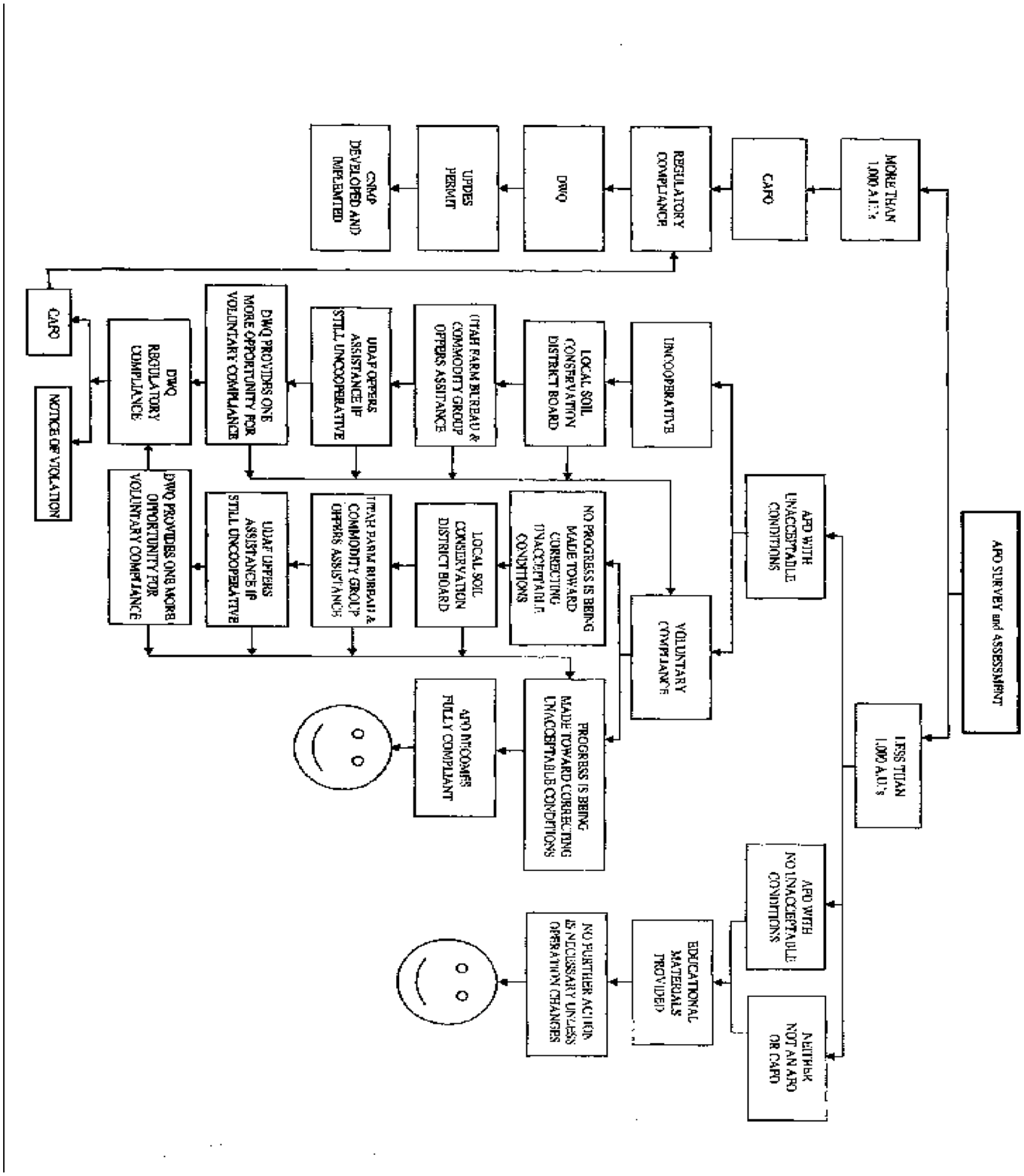

Figure 10. Utah AFO Water Quality Strategy Process

The producers also had an understanding of runoff impacts and had a similar concern for protecting the waters in the areas in which they live. With the shared goal of improving the quality of the water resources, regulators were able to understand the other concerns of the producers and help them secure loans and grants to fund construction projects while surviving in a low profit margin industry. By 2004, more than $7.1 million in federal and state funds have been utilized to further the program in the State of Utah (Loveless et al., 2004).

The biggest difference in the Utah strategy is the "potential" CAFO (PCAFO) designation. This allows smaller operations with runoff problems a flexible window of opportunity to fix problems and come into compliance while still qualifying for federal funds, an opportunity that regulated operations do not receive.

Another hallmark of the Utah program was its approach to protecting confidential grower information. Data on individual farms are closely held by the growers as well as the USDA Agricultural Statistics Office and proved to be among the most difficult issues. Ultimately, the Utah Farm Bureau Federation served as an intermediary for sensitive data and were held responsible for reporting to State regulators. This approach made regulators uneasy, but the State and USEPA Region VIII eventually agreed to move ahead and see if such a non-traditional strategy would accomplish the ultimate environmental results.

The gamble paid off handsomely. Even before the completion of the Utah AFO Strategy, work began under the direction of the Utah Farm Bureau Federation and the Utah Association of Conservation Districts to conduct on-farm assessments of every animal feeding operation in the state. By 2004, essentially all of the 2915 on-farm AFO assessments were complete. In contrast the State of Colorado reported that by 2004, 40 farms had been inspected under a traditional regulatory program (Colorado Department of Public Health and the Environment 2004).

The committee determined that 2056 of the 2915 AFOs (71%) had no water quality problems. They identified 58 CAFOs and 392 PCAFOs for a total of 450 sites. Of these, 391 have completed CNMPs, 234 have controlled runoff, 220 reduced runoff by implementing CNMPs and fell below PCAFO thresholds, and 264 are in full compliance (Petersen 2006). An example of one of hundreds of projects from the program is shown in Figure 11. The project consisted of manure bunkers and evaporation pond in the foreground plus a buffer zone before a stream in the distance.

Figure 11. Lane Sorenson Farm, Sanpete County, Utah

Assessments were accomplished and permits issued much faster than other state programs. More importantly, farmers implemented best management practices (BMP) promptly with nitrogen, phosphorous, and Biological Oxygen Demand (BOD) loadings reduced 95% by 2005 (Loveless et al., 2004, Petersen 2006). These goals were accomplished with minimal increases in the size of the regulatory agencies charged with implementing the new federal programs.

Controlling Air Pollution from AFOs: The USEPA AFO Compliance Agreement Proposal

On January 21, 2005, EPA announced a program for farmers to participate in an Animal Feeding Operations Air Quality Compliance Agreement to resolve non-compliance and fund air monitoring of AFOs (Federal Register 2005). The USEPA strategy began with an enforcement-based action to generate funds for a monitoring program from penalties and fees. The agency hopes to monitor 28 sites throughout the nation for swine, poultry, and dairy cows. The results will be used to calculate emission factors based species and other parameters that might affect emission rates. The emission rates could then be used to determine if farms comply with the Clean Air Act Operating Permit and New Source Review (NSR) permitting programs, Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) reporting, and the Emergency Planning and Community right-to-Know Act (EPCRA) reporting.

Since agricultural emission factors can be highly variable, actual emissions are not generally well defined so most operations do not know whether they are in compliance with federal environmental laws or not. The USEPA solicited farmers to pay fees and penalties regardless of their ultimate compliance status to provide protection from future enforcement action based on past emissions.

The federal enforcement-centric plan suffers from some other shortcomings. It does not include a plan to reduce emissions, measure reductions, or determine Best Available Control Technologies (BACT) or Best Management Practices (BMP) as substantive objectives of the study. The key objective is to find out who is or is not in compliance. Based on the water quality program results, meaningful emissions reductions could take 5-10 years. The single media focus could hamper or reverse successful water quality and animal waste management efforts. Finally, the proposed USEPA Consent Order creates an adversarial relationship symbolizing a breakdown of the "policy-making triangle" rather than a problem solving partnership that promotes more lasting strategies. Not surprisingly, the question of confidential grower information is also a major issue in the national program. Many states and environmentalists are suspicious when critical data is not transparent so it will be interesting to see how USEPA finally addresses this concern. Achieving the same degree of trust on a national scale is far more difficult than in a single small state. This might suggest there is an opportunity for other states to pursue their own tailored strategies to avoid or minimize some of the challenges of a single national effort. It may also be easier to produce a strategy at the state scale that minimizes economic impact on agriculture while achieving equivalent or superior environmental results.

Utah's Air Quality Requirements

The State of Utah has been delegated authority to implement all programs allowed in the Clean Air Act. Key air programs with possible applicability to agriculture are the National Ambient Air Quality Standards (NAAQS), NSR Prevention of Significant Deterioration of Air Quality (PSD) permitting program, and the Operating Permit program. In addition, Utah has a minor NSR program for sources with less than 250 tons of emissions per year that are not regulated by the federal PSD program. The minor NSR program requires Best Available Control Technology on all sources not directly regulated by any federal air quality standard with actual emissions more than 5 tons per year of sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOC), or more than 500 pounds of any single hazardous air pollutant or 2000 pounds of any combination of hazardous air pollutants (Utah Code Annotated 2005).

The very low permitting thresholds for the minor NSR program could likely ensnare a large number of small agricultural operations in a permitting system designed for industrial sources. Utah officials immediately recognized the opportunity to extend the successful Water Quality AFO partnership to address air quality requirements as a viable alternative to the normal NSR permitting process.

Utah Strategy for Air Pollution from AFOs

Most Utah farmers did not feel the proposed USEPA national monitoring settlement was useful to them. It was costly and would not yield data relevant to arid agricultural practices in the intermountain West since none of the 28 federal program sites would be in the region. The AFO Committee created an air strategy that was formalized through a Memorandum of Understanding with USEPA Region VIII in August 2005 (Roberts and Nielson 2005). The MOU contains commitments for timely monitoring using approved protocols and quality assurance procedures. A major focus of the Utah program is evaluation of BMPs so solutions can be accelerated and multimedia impacts evaluated. The Utah partnership stands in sharp contrast to the far more contentious national effort that has limited emphasis on BMPs and cross-media impacts.

The Utah Air Quality Strategy has the overall goal to meet the requirements of state and federal environmental regulations while maintaining a viable agricultural industry in the State of Utah. The State wanted to commence immediate steps to evaluate and implement agricultural practices that will minimize overall environmental impact similar to the AFO Water Quality Strategy by expanding the scope of Utah's existing Agriculture - Environmental Partnership. The air strategy needed to constructively engage EPA to augment, not compete with, the federal AFO program and assist in funding, evaluating, and approving options as a means of achieving national objectives in Utah. As with the national program, Utah's first objective was to rapidly assess air quality issues and the impacts of animal feeding operations. Since no federal monitoring sites were slated for the intermountain West, the State needed to determine how to measure or quantify emissions and harmonize the methods with the national program protocols. Utah also wanted to determine air quality and cross-media (water quality and waste) BMPs for species and type of operation as an integral part of the entire process. It was also essential to quantify results and measure progress in actual reductions in air contaminants released from the very beginning of the effort. This was a feature of the water quality strategy that jump started environmental results. It is believed that such early results and broader industry penetration could provide a measure of relief from litigation. All in all, the program was viewed as providing Utah growers with a viable alternative to EPA's national Consent Order although growers were free to participate in both programs. Concurrent with the program planning effort was a successful drive to secure funding for testing and to assist growers in implementing viable BMPs.

Based on the proceeding principles, a Utah AFO Air Quality Plan was developed with specific objectives, schedules and metrics. The plan's objectives are to:

1) Quantify air emissions from Utah's confined animal feeding operations. Specifically:
    a. Identify emissions: Ammonia (NH_3), Volatile Organic Compounds (VOC), Nitrogen Oxides (NO_X), Carbon Monoxide (CO), Hydrogen Sulfide (H_2S), Particulate matter (PM_{10} and $PM_{2.5}$), Hazardous Air Pollutants (HAPs) and other air contaminants.
    b. Identify species: Swine, dairy cows, poultry (turkeys, broilers, layers).
    c. Select monitoring locations that cover range of geographic and other factors.
    d. Determine relationships of emissions under various conditions for example determine if NH3 emissions increases when H2S in controlled.
    e. Select monitoring locations with a range of BMPs in place for water and waste management.
    f. Emphasize emission evaluations during valley wintertime inversions and sub-freezing temperatures.
    g. Write test protocols to include Quality Assurance plan and statistical methods.
    h. Conduct emissions testing.
    i. Report results.
2) Develop emission factors for species, physical management practices and BMPs.
3) Determine what BMPs could be considered BACT.
4) Identify where air quality BMPs could degrade water quality BMPs for waste and vice versa.
5) Determine operations that may be subject to CAA permitting (Approval Order or Operating Permit) and CERCLA/EPCRA requirements.
6) Develop multi-media implementation plan that:
    a. Starts with a voluntary, incentive-based approach,
    b. Meets CAA regulatory requirements, and
    c. Builds on the success of the Water Quality program to maximize Air, Water and Waste benefits.

With funding from State and Federal sources anticipated by March 1, 2006, purchase of equipment and field work is anticipated to begin by mid-2006. The Utah Division of Air Quality will be program manager with USU faculty serving as principal investigators. The program results will be further leveraged by two separate, but concurrent, investigations. USU scientists and engineers have spearheaded research to characterize unusually high PM2.5 levels in the Cache Valley where the university is located and is home to a significant dairy industry. In addition, ongoing national research by USUs Space Dynamics Laboratory to develop new state of the art analytical methods of for particulate measurements may further enhance program results.

Conclusions

Collaborative methods can often lead to better, more timely, and more durable environmental results than a traditional regulatory paradigm. Stakeholder processes can be time intensive upfront and may not always be fully successful if stakeholders are not committed to solutions, but they can be highly beneficial environmentally even if the ultimate legal outcome is in question. If the process does fails for a specific problem, it can lead to relationship that could be valuable in dealing with a future environmental impasse.

References

Amar P., et al. 2002. (Note: Mr. Amar was one of 31 Work Group members listed in the report who jointly authored the report.) Recommendations for the Utility Air Toxics MACT, Final Working Group Report. Subcommittee for Permitted/New Source Review/Toxics, Clean Air Act Advisory Committee. October, 2002.

American Corn Growers Association v. EPA . 2002. American Corn Growers Association v. EPA, 291 F.3d 1 (D.C. Cir. 2002)

Becker, S.W. 2005. News Release from the association of State and Territorial Air Pollution Program Administrators and Association of Local Air Pollution Control Officials, EPA Mercury Utility Rule will not Protect Health and Environment, Say State and Local Air Officials. March 15, 2005.

Buttars, L., 2005. Davis Count Official Still Wants Rocky's Apology. Salt Lake Tribune, February 10, 2005.

Center for Energy and Economic Development vs. EPA. 2005. Center for Energy and Economic Development v. EPA, No. 03-1222)D.C. Cir, February 18, 2005).

Chu, P., N. Goodman, G. Behrens, and R. Roberson. 2001. Total and Speciated Mercury Emissions from U.S. Coal-fired Power Plants. Electric Utilities Environmental Conference. Tucson, AZ, January 9, 2001. http://www.epri.com/attachments/262300_EUEC_pchu_1-01.pdf (February 15, 2006)

Code of Federal Regulations. 2001. Code of Federal Regulations, Chapter 23, Federal Highway Administration, Department of Transportation, Subchapter E, Planning and Research, Part 450, Planning Assistance and Standards, October 16, 2001.

Colorado Department of Public Health and the Environment 2004. Annual Report to the Water Quality Control Commission, Fiscal Year 2003-2004, Water Quality Control Division, Colorado Department of Public Health and Environment, October 1, 2004.
(http://www.cdphe.state.co.us/op/wqcc/WQCD_reports/wqccannrep0304.pdf page 10)

Cummins, P., 2005. Western Regional Air Partnership Board Meeting Proceedings, Executive Director's Report, Palm Springs, CA. December 15, 2005.

Ewing, J., 2002. Press Release from Office of the Mayor of Salt Lake City. Host City Mayor Calls for Olympic Fair Play. February 22, 2002.

Federal Register. 1997. 62 FR 41138 Regional Haze Rule Proposal. July 31, 1997.

Federal Register. 1999. 64 Federal Register 35714. Regional Haze Rule. July 1, 1999.

Federal Register 2004. 69 FR 40274, Prevention of Significant Deterioration (PSD) and Non-attainment New Source Review (NSR): Equipment Replacement Provision of the Routine Maintenance, Repair and Replacement Exclusion; Stay; Final Rule. July 1, 2004.

Federal Register. 2005a. 70 Federal Register 4958. Animal Feeding Operations Consent Agreement and Final Order; Notice. January 31, 2005.

Federal Register. 2005b. 70 FR 28606, Standards of Performance for New and Existing Stationary Sources: Electric Steam Generating Units. May 18, 2005.

Grand Canyon Visibility Transport Commission. 1996. Final Report. (June 10, 1996)

Loveless, R; M.M. Petersen, K. Goodrich, N. Hansen, P. Gessel, R. Gunnell, and J. Wilbur. 2004. Utah! Animal Feeding Operation Strategy: Five Years of Progress 1999-2004.

National Governors Association (NGA). 2000. NR-01. *Enlibra*: A New Shared Doctrine for Environmental Management Policy. December 19, 2000.

Nielson, D.R. 2004. The Role of Science in Making Natural Resources Decisions. Geological Society of America, Rocky Mountain Section (56th Annual) and Cordilleran (100th Annual) Joint Meeting. Boise, ID. May 3, 2004.

Peterson, M.M. 2006. Presentation to the Utah AFO Committee. Progress Report. February 15, 2006.

Roberts, R.E. and D.R. Nielson. 2005. Cover Letters for Memorandum of Understanding between the Utah Department of Environmental Quality and the U.S. Environmental Protection Agency, Utah Animal Feeding Operation Air Quality Strategy, dated August 3, 2005, and August 5, 2005, respectively.

Tilton, A. 2006. H.B. 259 Substitute 1, Division of Air Quality - Bond for Stay of an Order. January 31, 2006.

United States Code. 1990a. Clean Air Act Sec 2112(n)(1), Electric Utility Steam Generating Units, November 15, 1990.

United States Code. 1990b. Clean Air Act Sec 2169B(f), Grand Canyon Visibility Transport Commission, November 15, 1990.

USEPA. 2003. EPA Publication No. EPA 454/ K-03-001, "Latest Findings on National Air Quality 2002 Status and Trends."

USEPA. 2005. Fact Sheet - Reconsideration of the Clean Air Mercury Rule. http://www.epa.gov/air/mercuryrule/fs20051021a.html (February 15, 2006)

Utah AFO/CAFO Committee. 2001. "A Utah Strategy to Address Water Pollution from Animal Feeding Operations," March 16, 2001.

Utah Code Annotated. 2005. 19-2, Air Conservation Act, 2005.

Wasatch Front Regional Council. 2005. Meeting Minutes, October 27, 2005.

West, S. 2006. "Legacy Gets Corps Permit," Ogden Standard Examiner, January 24, 2006.

Western Governors' Association (WGA), 1998. Policy Resolution 05-17, Breckenridge, Colorado. Reauthorized June 12, 2005. Principles for Environmental Management in the West. http://www.westgov.org/wga/policy/05/enlibra.pdf (February 8, 2006)

Modeling Agricultural Air Quality: Current Status, Major Challenges, and Outlook

Yang Zhang[1], Shiang-Yuh Wu[2], Jianlin Hu[1], Srinath Krishnan[1], Kai Wang[1], Ashley Queen[1], Viney P. Aneja[1], and Pal Arya[1]

[1]Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC, 27695-8208

[2]Department of Environmental Quality, Richmond, VA, 23240

Abstract

Agricultural air quality is an important emerging area of atmospheric sciences that represents significant challenges in many aspects of research including measurements, modeling, regulations, emission control, and operation managements. This work presents a review of current status, major challenges, and future research opportunities of agricultural air quality modeling.

Introduction

Current air quality research focuses largely on criteria pollutants such as nitrogen oxides (NO_x), ozone (O_3), and particulate matter (PM). Limited attention has been given to non-criteria air pollutants such as nitrogen- and sulfur-containing compounds from agricultural sources (e.g., ammonia (NH_3), nitrous oxide (N_2O), hydrogen sulfide (H_2S)). Agriculture provides a major source of those compounds. For example, 90% of the atmospheric burden results from animal production and emissions from slurries and manures in the U.S. (Davison and Cape, 2003) and many European countries (Sutton et al., 1995; Van Der Hoek, 1998; Hutchings et al., 2001; Sotiropoulou et al., 2004). Growing evidence has shown that the increased size and geographical concentration of animal-feeding operations (AFOs) and agricultural crop production are increasing the emissions of odor (e.g., organic acids) and trace gases (e.g., carbon dioxide (CO_2), methan (CH_4), NO_x**,** NH_3, and H_2S) to the atmosphere (e.g., Kurvits and Marta, 1998; NRC, 2003; Aneja et al., 2006). Increases in the emissions of those agriculturally emitted compounds in the U.S. and abroad and their adverse impacts on the quality of the air, water, soil, the biodiversity, and the entire agro-ecosystem have raised growing public and regulatory concerns. Those concerns have led regulators and policy makers from the U.S. and other countries to begin considering mitigation strategies for agriculturally emitted air pollutants. Regulations for NH_3 emission reductions from the livestock farming have been initiated and enforced in the Netherlands to meet stringent emission and deposition of NH_3 targets (Lekkerkerk, 1998). In the U.S., although there is currently no national ambient air quality standards (NAAQs) for those agriculturally-emitted air pollutants, a reporting requirement for the large released quantities of NH_3 and H_2S from AFOs has been enforced under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA), as part of the Clean Water Act (CAA). In addition, mitigation measures are being taken at a state level. For example, both Minnesota and Texas have state ambient air quality standards for H_2S; the North Carolina Environmental Management Commission is one of the first agencies in the U.S. to adopt rules for odor control from swine farms in 1999**.**

Advanced 3-D AQMs accounting for emissions, transport, transformation, and removal of air pollutants provide a powerful tool to simulate the fate, distributions, and impact of agriculturally-emitted air pollutants. National Research Council has clearly identified a need for such three-dimensional (3-D) transport/transformation models in providing scientific basis for the development of relevant mitigation strategies (NRC, 2003). The current status of agricultural air quality modeling and the future research needs and challenges are provided below.

Summary of Review Results

The development of feasible regulations of air emissions from AFOs requires a scientific basis that is currently lacking due largely to inadequate funding from governmental agencies and little attention from scientific communities for agricultural air quality research. Knowledge gaps and critical needs for agricultural air quality research have been recently identified by National Research Council (NRC, 2003) and the USDA Agricultural Air Quality Task Force (http://www.airquality.nrcs.usda.gov/AAQTF/). Significant uncertainties lie in nearly all aspects of research including the sparseness of monitoring stations and observational data of emissions, concentrations, and deposition fluxes, the lack of accurate emission inventories and reliable measurement methodologies, poorly-quantified health-effect associated with the AFOs-emitted species, and the need for process-based emissions models and 3-D transport/transformation models to support regulation and policy-making.

Current 3-D urban-to-regional air quality models (AQMs) are designed to simulate the sources, transport, chemical transformation, and removal of major criteria air pollutants such as sulfur dioxide (SO_2), NO_x, O_3, and PM and its composition (e.g., sulfate (SO_4^{2-}), nitrate (NO_3^-), ammonium (NH_4^+)), and the important gaseous precursors of O_3 and PM such as NH_3 and volatile organic compounds (VOCs). Among all agriculturally emitted compounds, NH_3 is the only species that is simulated in 3-D urban-to-regional AQMs but large uncertainties remain in its emission inventories, chemistry, and dynamic treatments. Current urban-to-regional AQMs do not treat other agriculturally emitted species such as N_2O and H_2S. The important processes of NH_3/NH_4^+ simulated in those AQMs include advection, diffusion, aerosol thermodynamics and dynamics (e.g., gas/particle partitioning, thermodynamic equilibrium reactions, condensation/evaporation, and coagulation), dry deposition, the dissolution in cloud droplets and rain water, and subsequent scavenging and wet deposition (e.g., Byun and Ching, 1999; Binkowski and Roselle, 2003; Zhang et al., 2004; Zhang and Jacobson, 2005; Zhang et al., 2006). Growing evidence has shown that NH_3 may play an important role in new particle formation through ternary nucleation involving sulfuric acid (H_2SO_4), water vapor (H_2O), and NH_3 (e.g., Coffman and Hegg, 1995; Weber et al., 1997, 1999, 2003; Kim et al., 1998; Korhonen et al., 1999; Kumala et al., 2000). This process has recently be incorporated into CMAQ (Zhang et al., 2005), although it has not yet been included in most other AQMs.

Compared with criteria air pollutants, modeling studies on agriculturally emitted pollutants are sparse on all scales. Several modeling studies of reduced nitrogen ($NH_x = NH_3 + NH_4^+$) have been conducted on a global scale or a large continental scale at a relatively coarse resolution from 150 × 150 km to 10° × 10° (e.g., Dentener and Crutzen, 1994; Galperin and Sofiev, 1998). Urban-to-regional simulations using 3-D Eulerian or Lagrangian chemistry and transport models at finer resolutions of 5 × 5 km to 80 × 80 km have also been performed but focused primarily on European countries (e.g., Galperin and Sofiev, 1998; Metcalfe et al., 1998; Ambelas SkjØth et al., 2004) and are very limited in other regions (e.g., in the Kanto region of Japan (Sakurai et al., 2005); in the eastern U.S. (Mathur and Dennis, 2003); and in the southern U.S. (e.g., Wu et al., 2005; 2006)). To study the fate of NH_3 emissions and its impact on PM formation, a comprehensive 3-D modeling is being conducted by the lead author's air quality modeling group at North Carolina State University. Two 1-month baseline simulations have been conducted using the US-EPA's modeling system for August and December, 2002 in a Southeast U.S. domain that covers primarily the state of North Carolina at a 4-km horizontal grid spacing **(**Wu et al., 2005, 2006**)**. The US-EPA's modeling system consists of the Pennsylvania State University (PSU)/National Center for Atmospheric Research (NCAR) Mesoscale Modeling System Generation 5 (MM5) version 3.7 (http://www.mmm.ucar.edu/mm5/mm5v3.html), the Carolina Environmental Program's (CEP) Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System version 2.1, and Community Multiscale Air Quality (CMAQ) modeling system (Binkowski and Roselle, 2003) version 4.4 with the Process Analysis technique. The initial and boundary conditions for MM5 and CMAQ simulations at a 4-km grid spacing are developed based on the Visibility Improvement State and Tribal Association of the Southeast's (VISTAS) Phase II modeling study at a 12 km grid spacing (http://www.vista-sesarm.org.asp). A comprehensive evaluation of both meteorological and chemical conditions along with a detailed process analysis for the baseline simulations are being performed (Krishnan et al., 2006; Wu et al., 2006; Queen et al., 2006). The baseline simulation results are evaluated using the observational datasets from national and state-owned networks such as the Interagency Monitoring of Protected Visual Environments (IMPROVE), the EPA Speciation Trends Networks (STN), the Clean Air Status Trends Network (CASTNet), and the North Carolina Department of Environment and Natural Resources (NCDENR). The relative importance of meteorological and chemical processes for $PM_{2.5}$ and its composition such as SO_4^{2-}, NO_3^-, and NH_4^+ and gaseous precursors such as NH_3, NO_x, and SO_2 is being examined. The likely reasons for the discrepancies between the simulated and observed meteorological variables and chemical concentrations are being identified. The sensitivity of the predicted precipitation and wet deposition amounts to the cloud microphysical modules is being studied using two cloud microphysical modules (Queen et al., 2006). The sensitivity of the predicted dry deposition amounts to important dry deposition module parameters (e.g., dry deposition velocity and resistance) is evaluated (Krishnan et al., 2006). The gas/particle partitioning of NH_3/NH_4^+ is studied using both CMAQ and several aerosol thermodynamic modules in order to understand the formation of ammonium salts under various meteorological and chemical conditions (Wang et al., 2006; Hu et al., 2006). In addition to the inaccuracies in the simulated meteorological field and the uncertainties in the model treatment for aerosol dynamics and chemistry and dry/wet deposition, the inaccuracies in the estimation of NH_3 emissions can have a large effect on the model performance on ammonium, nitrate, and $PM_{2.5}$. Sensitivity simulations have thus also been conducted to evaluate the accuracy of the NH_3 emission inventory used and the impact of emission adjustments on overall model predictions (Hu et al., 2006).

Large uncertainties in current agricultural air quality modeling lie in several aspects including (1) inaccurate emission inventories as a result of inaccurate emission factors for various source categories from animal operations and crop production and the use of different methods to generate the inventories; (2) simplified model treatments of chemical and physical processes (e.g., gas/particle partitioning, dry and wet deposition modules); (3) inaccurate meteorological predictions (e.g., fraction velocity and precipitation); (4) lack of a detailed information on terrain characteristics and land use (e.g., surface roughness and vegetation types); and (5) paucity of observational data of emissions, concentrations, and deposition amounts for model verification and evaluation. In this review, uncertainties associated with each of these aspects will be reviewed in detail. Model simulation results from several case studies conducted in several domains (e.g., the southeastern U.S. and the state of North Carolina) by the lead author's group will be presented. The deficiencies and uncertainties in current AQMs, model inputs, and measurements will be indicated along with recommendations regarding potential model improvements and data needs. Finally, the important implications of results from 3-D AQMs in developing relevant regulations and control strategies for agricultural air quality as well as future research opportunities for studying agriculture-related pollutants and their impacts on air quality, human health, and regional climate will be discussed.

Acknowledgements

This work is sponsored by the National Science Foundation Career Award No. ATM-0348819 and the United States Department of Agriculture 2004-35112-14253 at NCSU. Authors would like to thank Mike Abraczinskas, George Bridgers, Wayne Cornelius, and Karen Harris of NCDENR for providing emissions, initial and boundary conditions, and CMAQ modeling results with a 12-km grid spacing from the VISTAS program, as well as the observational dataset for chemical species in the state of North Carolina; Don Olerud, BAMS, Inc., for providing VISTAS's MM5 simulation results at a 12-km grid spacing.

References

Ambelas SkjØth, C., O. Hertel, S. Gyldenkarne, and T. Ellermann, 2004, Implementiung a dynamic ammonia emission parameterization in the large-scale air pollution model ACDEP, *J. Geophys. Res.*, 109, D06306, doi:10.1029/2003JD003895.

Aneja, V.P., W. H. Schlesinger, D. Niyogi, G. Jennings, W. Gilliam, R. E. Knighton, C. S. Duke, J. Blunden, and S. Krishnan, 2006, Emerging national research needs for agricultural air quality, *EOS, Transactions, American Geophysical Union*, 87(3).

Byun, D., and J. Ching, 1999, Science algorithms of the EPA Models-3 community multi-scale air quality (CMAQ) modeling system, *Rep. EPA/ 600/R-99/030*, Natl. Exposure Res. Lab., Research Triangle Park, N.C.

Binkowski, F.S., and S.J. Roselle, 2003, Models-3 community multiscale air quality (CMAQ) model aerosol component, 1. Model Description. *J. Geophys. Res.*, 108, 4183, doi:10.1029/2001JD001409.

Coffman, D.J. and D.A. Hegg, 1995, A preliminary study of the effect of ammonia on particle nucleation in the marine boundary layer, *J. Geophys. Res.*, 100, 7147-7160.

Davison, A. W. and J. N. Cape, 2003, Atmospheric nitrogen compounds-issues related to agricultural systems, *Environ. International*, 29, 181-187.

Dentener, F.J. and P. J., Crutzen, 1994, A three-dimensional model of global ammonia cycle, *J. Atmos. Chem.*, 19, 331-369.

Galperin, M.V. and M.A., Sofiev, 1998, The long-range transport of ammonia and ammonium in the Northern Hemisphere, *Atmos. Environ.*, 32 (3), 373-380.

Hu, J.-L., S.-Y. Wu, Y. Zhang, V. P. Aneja , G. Pouliot, A. Gilliland, and R. Pinder, 2006, Ammonia emissions and their implications on fine particulate matter formation in North Carolina, to be presented as a poster at *the Workshop on Agricultural Air Quality: State of the Science*, June 5-8, 2006, Potomac, MD.

Hutchings N. J., S. G., Sommer, J. M. Andersen, and W.A.H. Asman, 2001, A detailed ammonia emission inventory for Denmark. *Atmos. Environ.*, 35, 1959 –1968.

Kim, T.O., T. Ishida, M. Adachi, K. Okuyama, and J.H. Seinfeld, 1998, Nanometer-sized particle formation from $NH_3/SO_2/H_2O$/air mixtures by ionizing irradiation, *Aerosol Sci. Tech.*, 29, 111-125.

Korhonen, P., M. Kulmala, A. Laaksonen, Y. Viisanen, R. McGraw, and J. H. Seinfeld, 1999, Ternary nucleation of H_2SO_4, NH_3, H_2O in the atmosphere, *J. Geophys. Res., 103,* 26,349-26,353.

Krishnan, S., Y. Zhang, V. P. Aneja, S.-Y. Wu, and R. Mathur. 2006, Modeling study of dry deposition of ammonia in North Carolina, to be presented as a poster at *the Workshop on Agricultural Air Quality: State of the Science*, June 5-8, Potomac, MD.

Kulmala, M., L. Pirjola, and J.M. Mäkelä, 2000, Stable sulphate clusters as a source of new atmospheric particles, *Nature*, 404, 66-69.

Kurvits T. and T. Marta, 1998, Agricultural NH and NO emissions in 3 *x* Canada, *Environ Pollut.*, 102:187 –194.

Lekkerkerk, L. J. A., 1998, Implications of DUTCH ammonia policy on the livestock sector, *Atmos. Environ.*, 32(3), 581 –587.

Mathur R. and R. L. Dennis, 2003, Seasonal and annual modeling of reduced nitrogen compounds over the eastern United States: Emissions, ambient levels, and deposition amounts, *J. Geophys. Res.,*108 (D15), doi:10.1029/2002JD002794.

Metcalfe, S. E., J. D. Whyatt, and R. G. Derwent, 1998, Multi-pollutant modeling and the critical loads approach for nitrogen, *Atmos. Environ.*, 32(3), 401-408.

NRC, 2003, Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs, 286 pages, Ad Hoc Committee on Air Emissions from Animal Feeding Operations, Committee on Animal Nutrition, National Research Council, ISBN: 0-309-08705-8.

Queen, A., S. Krishnan, Y. Zhang, S.-Y. Wu , J. Pleim, S. Roselle, and R. Gilliam, MM5 precipitation physics and their impact on the wet deposition predictions of CMAQ, to be presented as a poster at *the Workshop on Agricultural Air Quality: State of the Science*, June 5-8, 2006, Potomac, MD.

Sotiropoulou, R. E. P., E. Tagaris, and C. Pilinis, 2004, An estimation of the spatial distribution of agricultural ammonia emissions in the Greater Athens Area, *The Science of the Total Environment*, *318*, 159–169, doi:10.1016/S0048-9697(03)00373-5.

Sutton M. A., C. J. Place, M. Eager, D. Fowler, and R. I. Smith, 1995, . Assessment of the magnitude of ammonia emissions in the United Kingdom. *Atmos. Environ.*, 29, 1393 –1411.

Van der Hoek, K.W., 1998, Estimating ammonia emission factors in Europe: summary of the work of the UNECE ammonia expert panel, *Atmos. Environ.*, 32, 315–316.

Weber, R.J., S. Lee, G. Chen, B. Wang, V. Kapustin, K. Moore, A. D. Clarke, L. Maildin, E. Kosciuch, C. Cantrell, F. Eisele, D. C. Thornton, A. R. Bandy, G. W. Sachse, and H. E. Fuelberg, 2003, New particle formation in anthropogenic plumes advecting from Asia observed during TRACE-P, *J. Geophys. Res.*, 108, 8814, doi:10.1029/2002JD003112.

Weber, R. J., J. J. Marti, P. H. McMurry, F. L. Eisele, D. J. Tanner, and A. Jeffersoon, 1997, Measurements of new particle formation and ultrafine particle growth rates at a clean continental site, *J. Geophys. Res.*, 102, 4375-4385.

Weber, R. J., P. H. McMurry, R. L. Mauldin III, D. J. Tanner, F. L. Eisele, A. D. Clarke, and V. N. Kapustin, 1999, New particle formation in the remote troposphere: A comparison of observations at various sites, *Geophys. Res. Lett, 26,* 307-310.

Wu, S.-Y., S. Krishnan, J.-L. Hu, C. Misenis, Y. Zhang, V. P. Aneja, and R. Mathur, 2005, Simulating atmospheric fate of ammonia in Southeast U.S. using CMAQ with a 4-km resolution, *the 4th Annual CMAS Models-3 User's Conference*, Sept 26-28. Research Triangle Park, NC.

Wu, S.-Y., J.-L. Hu, and Y. Zhang, 2006, Modeling transport and chemistry of ammonia in North Carolina: seasonality and process analysis, to be presented as a poster at *the Workshop on Agricultural Air Quality: State of the Science*, June 5-8, Potomac, MD.

Wang, K., Y. Zhang, M. Z. Jacobson, J.-Y. Liang, and K, Magliano, 2006, A study of gas/particle partitioning using inorganic thermodynamic equilibrium modules and data from the California Regional $PM_{10}/PM_{2.5}$ Air Quality Study, to be presented as a poster at *the Workshop on Agricultural Air Quality: State of the Science*, June 5-8, Potomac, MD.

Zhang, Y., B. Pun, K. Vijayaraghavan, S.-Y. Wu, C. Seigneur, S. Pandis, M. Jacobson, A. Nenes, and J. H. Seinfeld, 2004, Development and application of the model of aerosol dynamics, reaction, ionization and dissolution (MADRID), *J. Geophys. Res.*, 109, D01202, doi:10.1029/2003JD003501.

Zhang, Y. and M. Z. Jacobson, 2005, Implementation and Testing of EQUISOLV II in the CMAQ Modeling System, oral presentation at *the 2005 Models-3 Workshop*, September 26-28, Chapel Hill, NC.

Zhang, Y., P. Liu, A. Queen, C. Misenis, B. Pun, C. Seigneur, and S.-Y. Wu, 2006, A Comprehensive Performance Evaluation of MM5-CMAQ for the Summer 1999 Southern Oxidants Study Episode, Part-II. Gas and Aerosol Predictions, *Atmos. Environ*., in press.

Zhang, Y., P. Liu, K. Wang, M. Z. Jacobson, P. Bhave, S.-C. Yu, S. Roselle, and K. Schere, 2005, Predicting Aerosol Number and Size Distribution with CMAQ: Homogeneous Nucleation Algorithms and Process Analysis, oral presentation at *the 2005 Models-3 Workshop*, September 26-28, Chapel Hill, NC.

Implications of Poposed PM Coarse National Ambient Air Quality Standards (NAAQS) on Agricultural Sources

Bryan W. Shaw, Ron E. Lacey, and William Brock Faulkner
Texas A&M University, Department of Biological and Agricultural Engineering,
College Station, TX 77843, USA

Abstract

The US Environmental Protection Agency is currently assessing the need for a National Ambient Air Quality Standard for the coarse fraction of particulate material (PM_c), specifically, the fraction of particulate matter between 2.5 and 10 µm in aerodynamic equivalent diameter. EPA is primarily relying on epidemiological studies that examine the possible health effects of PM_c to reach a decision about developing a coarse particulate matter standard. These epidemiological studies utilize data from size-selective PM samplers to estimate the study population's exposure to PM_{10}, $PM_{2.5}$, and PM_c. Epidemiological studies typically focus on urban populations in order to obtain sufficient sample size and increase statistical certainty of study findings. This focus on urban environments has resulted in a lack of studies evaluating the effect of coarse particulate matter in rural environments. There are a number of key differences between the urban and rural environments in the United States that can lead to mistakes in applying data from urban studies to rural environments. These include differences in particle sources, affecting particle size distribution and composition, differences in the concentration of gaseous co-pollutants, and differences in PM sampler performance in the two environments. It is our contention that these differences between the urban and rural environment are significant and that the epidemiological studies cited by EPA rely on data that are not representative of rural environments, raising concerns that the implementation of a PM_c standard in rural environments will impose an unfair and unwarranted regulatory burden on the businesses and citizens in these areas.

Environmental Load of Ammonia in the Vicinity of Livestock Enterprises

T. Hinz
Federal Agricultural Research Centre, Institute of Technology and Biosystems Engineering, Braunschweig, Germany

Abstract

Animal production is the main source of ammonia emissions. Ammonia emissions are part of international strategies of prevention of air pollution and its control but also part of national regulations. At the present time reliable data of emission flows and reduction efficiencies are available from stable with forced ventilation only. Reflecting to naturally ventilated stables or free land keeping measurements of the ammonia concentration in ambient air in the vicinity of such sources may give a contribution to solve this problem.

A simple and cheap method is the use of passive samplers. Units with 4 single Ferm samplers each are mounted in the vicinity of poultry houses and close to a free land calf keeping. The study runs since June 2003 and is still running. Concentration levels range between 1 µg/m³ and more than 300 µg/m³. As main parameter the ambient temperature is identified, the progress in fattening is less important. Concentration decreases faster than assumed in some models. This result can be of interest if minimum distances are required between a livestock enterprise and e.g. forests or residential districts.

Aim of the study is to provide data on farm level. These data may be used in models to estimate source strength.

Introduction

In the past ammonia in the air of livestock buildings was seen as a problem of man and animal health and welfare only. But since a couple of years ammonia is considered as pollutant and agriculture is part of large scale air pollution and control strategies e.g. the UN ECE Convention on Long Range Transboundary Air Pollution (UN ECE 1979). In different protocols national emission ceilings are given. Some countries will keep other will exceed the limits.

Emissions of air pollutants may be measured directly as fluxes but mostly indirectly as the product of air flow rate and airborne concentration. At the present time reliable data of emission flows and reduction efficiencies are available from stableswith forced ventilation only. Reflecting to naturally ventilated stables or free land keeping measurements of the ammonia concentration in ambient air in the vicinity of such sources may give a contribution to solve this problem (Gärtner et al. 2004). A simple and cheap method is the use of passive samplers. Parallel with measurements of air quality inside the building (Hinz et al. 2004) first investigations using this technique were initiated 2003 on a turkey barn and are still running. Meanwhile broiler, calves and pigs will be tackled.

In the following the procedure and results are presented at the example of a turkey and calf enterprise.

Methods

The investigations were carried out in two commercial poultry farms and the experimental plant of the FAL:

1) Fattening turkeys in a stable with natural ventilation and a veranda
2) Fattening broilers in a stable with forced ventilation and free range
3) Fattening pigs in a stable with forced ventilation
4) Calves in free land keeping with cottages shown in figure 1.

Figure 1. Calves in free land keeping- location of one sampler to detect ammonia

In this paper method and results are given for the examples of turkeys and calves only.

To measure ammonia concentration passive sampler were used. In each case 4 samplers were mounted on 7 respectively 13 pales in a height of approximately 2.5 m above ground. In calf keeping the masts stood inside or at the border of the range. At the poultry houses the measuring positions were located in different distances. On the turkey farm these distances vary from 2 m near the curtains up to 167 m from the front wall of the barn. Figure 2 a), b) schematically gives the arrangements for calves and turkeys.

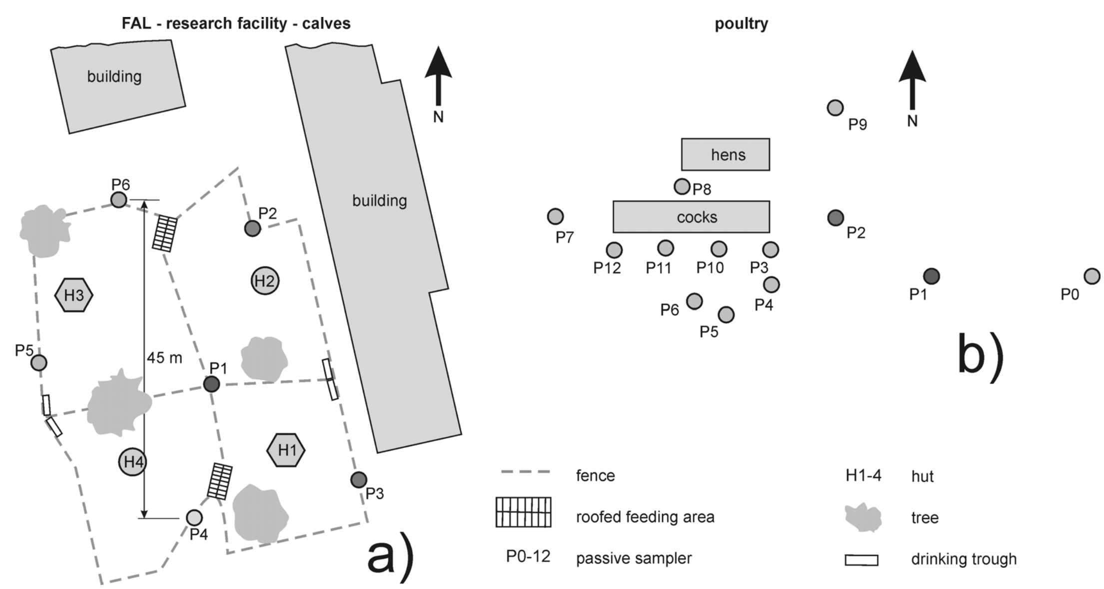

Figure 2. Arrangement of pales at calf a) and turkey b) enterprises

In the region of that turkey farm the main wind directions are west but, especially in winter must be noted east. It is to consider that in a distance of about 300 m from the turkey barn a lot of laying hens are housed. To get the information about wind speed and wind direction samplers had an ultra sonic anemometer was installed between the both houses but over roof height. All were changed periodically every 14 days. The campaign for calves was running for 9 months and is still running for the turkeys, whereby some locations had been changed with priority to pales in main wind directions.

The sampler itself was constructed according to Ferm figure 3.

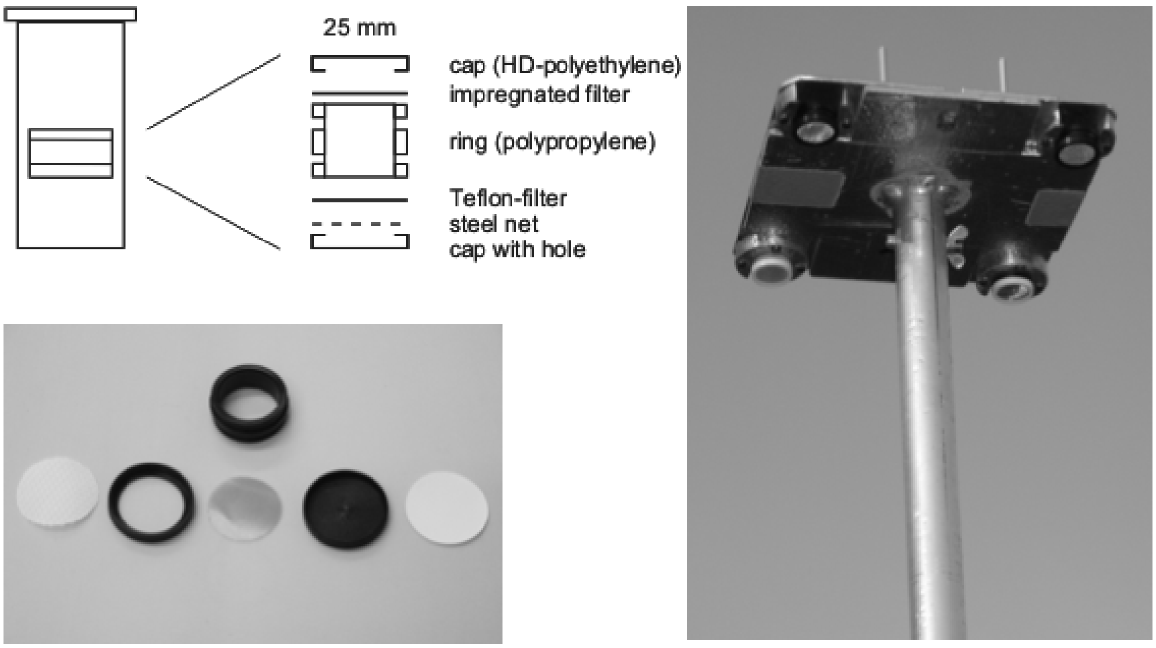

Figure 3. Passive sampler according to Ferm, details and arrangement on a pale

Ferm constructed this type of sampler short, broad and therefore sensitive for relatively low concentration in ambient air of the environment (Ferm 1991). A thin porous membrane filter was used to avoid turbulent diffusion inside the sampler. A filter covered with citric acid takes up the ammonia.

After sampling the filter is extracted and analysed. The result is an averaged concentration related to the sampling time.

Results and Discussion

Calves in Free Land Keeping

For calves in free land keeping ammonia concentration ranged between 1 µg/m³ and 60 µg/m³. Local dependencies were found with higher values in areas with feeding / mucking sites. The shape of the curves during the period of investigation is very similar and follows mainly the course of temperature. Figure 4 shows this finding on the example of pale 6, figure 2 a).

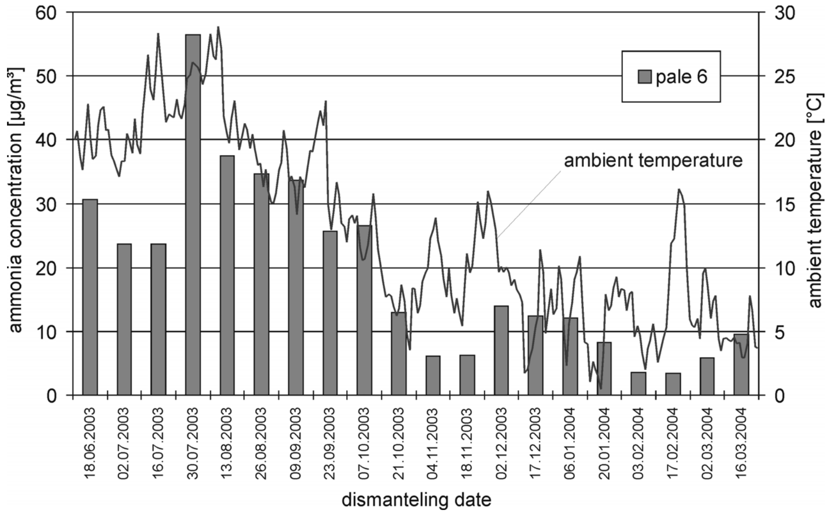

Figure 4. Course of ammonia concentration and ambient temperature at pale 6

After increasing to maximum values in July concentration and temperature go more or less continuously down to be below 10 µg/m³. This is the limit value in Germany to protect sensitive plants and ecosystems. Especially under the consideration that concentrations had been measured directly at the free range there is no relevant influence to the environment to be seen, caused by that calf keeping.

Turkey Enterprise

Depending on a much higher strength of the ammonia source and the large variety of the pale locations with respect to the distance from the houses, ammonia concentration was measured in a range between 1µg/m³ and more than 300 µg/m³ for single samples of 14 days duration each. Annual averages reached measures up to more than 100 µg/m³ for the closest pales - pale 3 and pale8. In figure 5 the annual averages and a three years average are plotted for all pales around the stables.

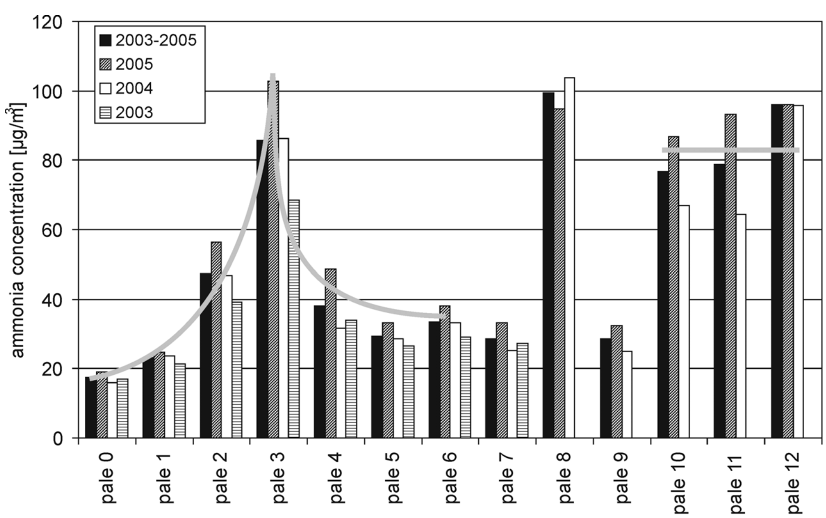

Figure 5. Averaged concentrations for all pales

There are some differences between averages but almost negligible. Comparison of pales 3 with the pales 2, 1 and 0 demonstrates a relatively sharp decrease of ammonia concentration with the distance of dispersion. 50 % reduction needs a distance of less than 40 m. A similar message gives the comparison of pale 3 with pales 4-6, which show concentration on the same level.

Sampling times of 14 days may mask influences of short-term events like mucking out at the end of a fattening period. To check this, samplers were mounted for two days only. The result is drawn in figure 6 in comparison with the normal conditions with birds inside.

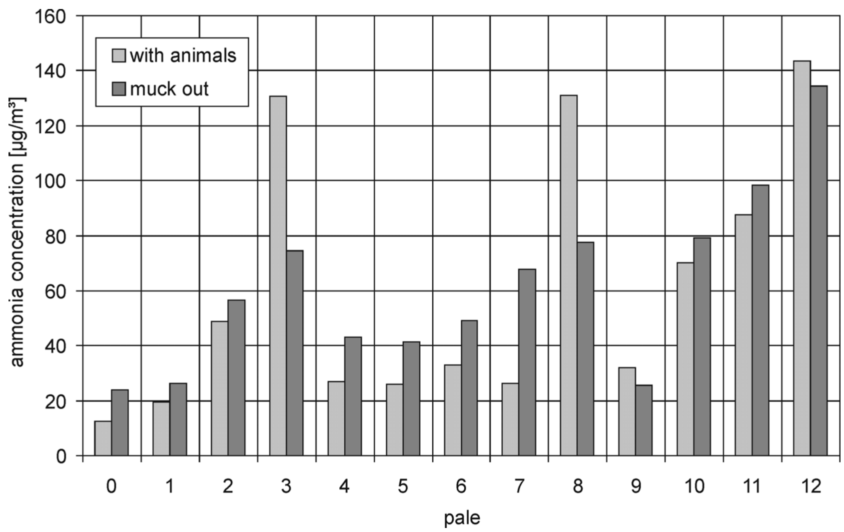

Figure 6. Ammonia concentration during fattening and mucking out

Passive sampler are able to detect short-term events. For most of the pales concentration during mucking is higher than during the attening period and will dominate the 14 days average.

Conclusion

Passive samplers according to Ferm are designed to determine low ammonia concentration in the ambient air. The investigations show that this technique is generally appropriate to measure in the vicinity of barns and other enterprises in animal production even if concentration reaches values up to 300 µg/m³ and more.

Averaging sampling times of 14 days but also short-term application for one or two days can be realized.

Local dependencies can be detected clearly.

As a main parameter the ambient temperature during the course of a year was found.

Measurements around a free land calf keeping showed concentration values between 1 µg/m³ up to 60 µg/m³ and 10 µg/m³ up to 300 µg/m³around the turkey barn in 14 days averages.

Ammonia concentration decreases relatively sharp verified by measurements done on a turkey fattening farm.

Considering local conditions and the run of a year there was no remarkable environmental impact in the investigated cases.

References

UN ECE (1979) Protocol to the convention of long-range transboundary air pollution to abate acidification, eutrophication and ground level ozone. United Nations Economic Commission for Europe (UN ECE), Geneva

Gärtner A, Hirschberger R, Hölscher N (2004) Abschätzung von gasförmigen Emissionen aus diffusen Quellen mit FTIR- und LIDAR- Fernmessverfahren. *Gefahrstoffe- Reinhaltung der Luft* 64, pp.263-269

Hinz T, Linke S, Berk J, Wartemann S (2004) The veranda- a new alternative housing system for fattening turkeys in Germany: impact of airborne contaminants and noise on animal health and the environment (CD-ROM). In Menesis JF, Silva LL, Baptista F (eds) New trends in farm building: International Symposium of the CIGR, 2nd Technical Section, May 02-06, Evora, Portugal

Ferm M (1991) A sensitive diffusional sampler. Swedish Environmental Research Institute, Göteburg. Report L91-192: 12 p