ANIMAL PRODUCTION AND AIR QUALITY

John M. Sweeten, PhD, P.E.
Professor and Resident Director
Texas A&M University Agricultural Research and Extension Center, Amarillo, Texas

Introduction

Concentrated animal feeding operations (CAFOs) as defined by USEPA are necessary for U.S. producers to meet growing domestic and world demands for livestock and poultry products. To maintain a safe and economical food supply, CAFO owners and operations must have access to cost-effective technologies, resources and sufficient lead-time to adjust to changing public agendas regarding air quality protection without disrupting the food supply. The USDA Agricultural Air Quality Task Force, created pursuant to the 1996 Farm Bill, identified air quality issues, approaches, and national research and education program needs associated with CAFOs (AAQTF, 2000). The following is a summary[1/] of that task force report prepared by a select group of scientists, engineers, producers, and public policy officials serving on the AAQTF. For further details, the reader should refer to the full text of that report on-line at http://www.nhq.nrcs.usda.gov/faca/Policies/CAFO.htm and many of the 100 or so references cited therein.

Discussion

Issues Overview

Animal agriculture in the United States is a $100 billion/year industry. The U.S. is the world leader in efficiency of producing meat, milk, poultry and eggs, as a direct result of increased development of concentrated animal feeding operations (CAFOs). The percentage of domestic livestock in concentrated animal feeding operations varies nationally and regionally by species from only 10% of the nation's beef cattle inventory to virtually 100% of swine and poultry. CAFOs have been closely regulated for the last 28 years or more under federal and state clean water laws, regulations and policies, and considerable funding has been directed to water quality research, demonstration, education, and technical assistance for CAFOs. Until recently, air quality from CAFOs has received only secondary consideration, notwith-standing recently-increased public concerns and policy attention. Water and air quality protection are inseparable, and the CAFO-related research, technology transfer, and federal and state programs should be linked accordingly and funded adequately, at levels commensurate with public concerns and with rapidly-developing scientific expertise at land grant universities and federal laboratories. Producers will need adequate lead-time, cost-effective technologies, and resources to adjust to changing public agendas that include air quality protection.

[1/]Adapted from: Sweeten, J. M., L. Erickson, P. Woodford, C. B. Parnell, K. Thu, T. Coleman, R. Flocchini, C. Reeder, J. R. Master, W. Hambleton, G. Bluhm, D. Tristao. 2000. Air Quality Research and Technology Transfer White Paper and Recommendations for Concentrated Animal Feeding Operations. Confined Livestock Air Quality Committee, USDA Agricultural Air Quality Task Force, Washington, D. C., July 19. 123 p.

CAFO Air Quality Parameters

CAFOs including swine and poultry operations, dairies and cattle feedlots, can affect air quality through emissions of: odor, odorous gases (odorants), particulates, and/or some of the so-called greenhouse gases. Sources include: open lots and confinement buildings, manure/wastewater storage or treatment systems, land application, and animal mortalities. Emissions load on the atmosphere is the product of contaminant concentration and airflow rate; and research is underway to develop and demonstrate cost-effective ways to reduce either or both these basic components.

Odor from CAFOs sources, as experienced by humans, is the composite of as many as 170 or more specific gases, present in trace concentrations either above or below their olfactory thresholds. Odor is characterized according to: strength (concentration or intensity), frequency, duration, offensiveness, and hedonic tone. Odor strength is measured by various types of dilutions-to-threshold devices (olfactometers) using human odor panelists; by determining the identity and concentration of individual odor gases; or by electronic "noses", which are in their infancy. Reproducible techniques for odor/odorant sampling, storage and transportation, and presentation to panelists have been developed, yet are undergoing further rapid development worldwide, because of high cost and labor requirements.

Odorous gases of concern today include ammonia and hydrogen sulfide. Considerable research in Europe and more recently in the U.S. has been devoted to monitoring these two fixed gases in and around confinement buildings, partly in relation to animal and human health concerns, and within and around open feedlots and dairies. However, the importance of ammonia and hydrogen sulfide to downwind composite odor as perceived by neighbors is questionable, according to evidence to date. Nevertheless, so-called emissions inventories that include data from often dissimilar systems in Europe have been compiled by EPA and used unwittingly in some states, despite thin and often specious databases.

In the U.S., ammonia emissions have long been encouraged as a legitimate means of balancing the nutrient equation for water quality protection purposes. Feeding and manure/wastewater management systems have been designed accordingly on a widespread basis. A reversal of form of a rather structural nature will be needed as water and air quality protection are now to be viewed conjunctively.

Field and laboratory research has largely focused on measuring concentrations of odor (e.g., odor units (OU)) or odorants (e.g., micrograms/cu. meter, or ppm) in air within and in close proximity to confinement buildings and open lot feeding systems. However, assessments of air quality impact also requires data on:

- emission rates (mass/unit time), e.g., kg/day;
- flux rates (mass/unit area/unit time), e.g., kg/sq. meter/day;
- emission factors (mass/unit of throughput/unit time), e.g., kg/head/year.

The AAQTF (2000) found a substantial number of data sources from the U.S. that provided *concentration data* from swine operations or from laboratory studies involving swine manure; not surprisingly, the preponderance of this data comes from the upper Midwest or from the mid-Atlantic states. Interestingly, ammonia emissions appear to occur with diurnal fluctuations, while hydrogen sulfide emissions occur in bursts from anaerobic storages or lagoons. To a lesser extent, similar data exists from poultry (Midwest and Southeast), dairy (Midwest, Northeast, and West Coast), and beef feedlot operations (Southern Great Plains and West Coast). However, a paucity of data exists on *emission rates*, *flux rates*, and *emission factors* from these sources and the many different manifestations of manure and wastewater management systems within each species. Where such data has been

reported, it shows a wide range; consensus numbers appear elusive. Further research by well-qualified and well-equipped laboratories is needed as a precursor to rational attempts to develop policies for CAFO odor and odorants.

It is believed that future research will be directed toward odorous gases that more closely correlate with odor as perceived by humans--the discerning public. Candidate compounds may include volatile organic compounds (VOCs) such as the volatile fatty acids, amines, alcohols, aliphatic aldehydes, p-cresol, indole, skatole, or mercaptans. The above comments on data quality and standardization of useful expression will apply as alternative compounds are studied and attempts made to relate them to odor.

Unlike odor and odorants, particulates have been explicitly regulated as one of six criteria pollutants under the Federal Clean Air Act since the 1960's. Total suspended particulate (TSP) standards for ambient air quality were replaced by PM_{10} standards in 1987, and recent USEPA proposals have addressed fine ("respirable") particulate, regarded as $PM_{2.5}$. Particulate sources from CAFOs include: feedmills, feedstuffs storage and handling areas, open lots, confinement buildings, roads and alleys, manure handling, solid manure storage or composting areas, and land application. Except for feedmills, these sources have been regarded as fugitive emission sources.

It has long been known that carbon dioxide and methane (non-odorous fixed gases of digestion and organic matter decomposition) are produced both by confinement and range/pastured livestock and poultry. Refinements in animal rations have improved digestibility, reduced manure loads, and shortened the production interval of meat animals, and thereby contributing to lowered emissions. With appropriate incentives for adoption, known technology for energy recovery from liquid manure treatment systems, together with state-of-the art open lot manure and holding pond management practices, producers may be able to further reduce emissions of these so-called greenhouse gases, which are not part of the regulatory fabric regarding air quality.

Emission Factors

Using old total suspended particulate (TSP) databases developed for other purposes, USEPA and its contractors of the 1970's extrapolated and subsequently synthesized original emission factors (published in AP-42) that have since been proved atypical by subsequent research. Refinements are in progress based on more accurate recent data that includes actual PM_{10} field measurements and modeling for cattle feedlots in the Southern Great Plains, where over 75% of he nation's beef cattle are fed for slaughter. Attempts to extrapolate air quality data from beef cattle feedlots over to dairy applications or other species or vice versa are ill-advised. It has proved inordinately difficult to correct poorly-conceived emission factors, notwithstanding new, superior data. Therefore, improved processes for updating emission factors for an array of CAFO-related air contaminants in the future should be developed.

Available data bases on $PM_{2.5}$ for CAFOs are very thin or nonexistent, although a few laboratories are becoming equipped to supply this data in the future for dairies and feedlots (California and Texas, for example). Evidence exists of rapid, predictable fluctuations of PM concentrations from open lot and animal confinement buildings alike owing to periods of heightened animal activity as triggering mechanisms, over and above more or less basal PM emission levels, possibly suggesting future topics of research and innovation, along with conventional control technologies.

Human Response and Health Effects

Concerns with health effects of odor, odorants, and PM from CAFOs extend to livestock health/performance issues, and to humans working within or living in proximity to such facilities. These

health-related issues, and applicable prevention technologies, may or may not be coupled. It appears that confinement swine facilities have been the focus of most of the research to date, followed perhaps by the poultry industry, as confinement buildings are the sites of highest air contaminant concentrations and exposure durations. One of the artifacts of increased animal concentration and industry consolidation may be an increased industry capacity to address both the on-farm as well as off-farm issues regarding potential health effects. Recent evidence suggests greater secondary health effects on frequently-exposed neighbors than previously documented, insofar as confined swine operations are concerned.

Current Federal and State Policies

Federal and state policies regarding CAFOs have been in existence for decades. Water quality concerns were addressed in the Federal Water Pollution Control Act of 1972, which listed CAFOs as point sources. Accordingly, federal effluent limitation guidelines (ELGs) and National Pollutant Discharge Elimination System (NPDES) or state-equivalent permits soon followed, and these were one-dimensionally focused on protecting surface water quality through no-discharge requirements. As documented in this report, individual States, and more recently USEPA regions (e.g., Region 6), subsequently have followed suit by adopting a virtual patchwork of tailored policies and regulations that have attempted to address voids of groundwater protection and nutrient management, and in a minority of cases air quality concerns, that were not addressed in USEPA's 1974-76 ELGs, which are still in effect. It is notable that USEPA has released for comment the basic concepts to be embodied into new ELGs for CAFOs (USEPA, 2001).

Integrated Programs

USDA agencies, land grant universities, and private industry associations, often times in partnerships with USEPA, local soil and water districts, and state environmental protection agencies, have launched coordinated research, education, training, technical and financial assistance programs to address water quality concerns and to enable the progressive attempts of CAFO operators to design and operate manure and wastewater management systems that address extant public policies as well as improve performance, productivity, beneficial use of nutrients, and minimize liability with respect to neighbors. Despite lingering problems in some areas or specific watersheds and notwithstanding public funding limitations, these programs plus the infusion of massive private investments on the part of CAFO operators have largely addressed the nation's water quality concerns and kept enormous quantities of manure and wastewater from being discharged off site and into streams, but rather put to beneficial use on crop or pasture land either on- or off-premises. Current or previous partnerships include the USDA interagency Water Quality Initiative, USDA/NRCS EQIP program; the National Pork Producers Council's Environmental Quality Assurance Program; and the new USDA/USEPA Unified National Strategy for Animal Feeding Operations, which will involve development of comprehensive nutrient management plans (CNMPs) for CAFOs. These are laudable programs.

However, no integrated counterpart programs to address air quality from CAFOs have been funded or developed. As a result, many operators may have facilities or systems optimized for water quality protection, but non-optimal with respect to emerging air quality objectives. It will take considerable time, investment, and a full measure of integrated, coordinated programs of research, education, training, technical and financial assistance to address air quality concerns adequately and co-extensively with water quality protection. Recent reactive, enforcement-related forays to target selected, individual operations with exposure to hazardous waste regulations designed for industry other than animal agriculture appear ill-conceived and counter to the systematic development and progressive implementation of an array of technologies that can ultimately find pervasive adoption by the CAFO industry of scientifically-sound, appropriate air pollution control technologies.

Odor Control Technologies

How can odor and odorants be satisfactorily controlled? There are four basic approaches, with multiple technologies that have possibilities within each approach:

- Ration/diet manipulation -- reduced protein levels; improved carbohydrate, nitrogen and sulfur utilization; synthetic amino acid supplementation; improved energy balances; copper supplementation (swine only); etc.
- Manure treatment -- aerobic conditions in surface manure (feedlots); drainage; frequent manure harvesting; lightly-loaded/facultative lagoons; multiple stage lagoons; surface aeration of lagoons or storage pits; experimental biochemical amendments; etc.
- Capture and treatment of emitted gases -- reduced liquid manure surface area; wet or dry scrubbers; dust control; biofilters; lagoon or storage pits covers; chemical oxidant surface sprays; non-thermal plasma reactors; etc.
- Enhanced dispersion -- excellent site selection; absence of confining valleys; adequate buffer distance; tree barriers; deflection walls (air dams); exhaust stacks; dispersion modeling; etc.

It should be cautioned that some of these technologies are as yet experimental in nature, or practical applications may not have been demonstrated. Likewise, selection of control technologies should be tailored to sources within site-specific circumstances that include facility design and management factors, climate, topography, and potential receptors.

Dust Control Technologies

Likewise, technologies for particulate (dust) control from open-lot feeding systems are available and include: frequent manure removal, stocking density adjustment to take advantage of excreted manure moisture, and where needed water sprinkling. Use of vegetable oil sprays has been demonstrated for use in swine confinement buildings, and terpenic sprays has reduced airborne bacterial infections in calf confinement barns. Speciation of CAFO-related dusts in contrast with ambient dusts from upwind operations (e.g., field dust from crop production operations) have not been determined heretofore.

Research Programs Needs: Health Effects

Worker health from exposure to dust, odor and odorants inside swine confinement facilities has received most of the attention regarding health-related issues of CAFOs. Respiratory diseases or conditions are generally more common among swine confinement building workers than among cohorts not similarly exposed. Commonly used design and management practices have been altered accordingly.

Recent attention has been paid to health complaints of rural residents neighboring large-scale swine confinement operations, with preliminary signs of mood states such as tension, anger, depression, or fatigue showing up recently in community surveys or epidemiological studies. Hydrogen sulfide is a suspected contributor. Linkages, if any, between concomitant control of odor, hydrogen sulfide, or any other specific gases, should be examined in future studies.

Research Funding Levels

Funding levels for air quality research regarding CAFOs are elusive. The GAO reported agency investments in a wide array of animal waste-related research (USDA-ARS averaged of $5.65 million per year (FY96-99) and USDA-CSREES reportedly $6.9 million in FY97), as compared to $15.7 million of state funds. However, the amounts attributed only to air quality were not reported separately, and are a subset of these totals. Current estimates by USDA-ARS are that the total amount in ARS projects that have expected outcomes of air quality enhancement is $2.9 million/ yr (Amerman, 2001). USDA-

CSREES identified 39 state research projects with some aspect of air quality in the project (Hegg, 2001). USEPA investments in agricultural air quality research are not reported and are likely miniscule. Both USDA and USEPA need to come to the table with enhanced long-term funding packages and programs for agricultural air quality research and technology transfer that specifically address CAFOs.

Research and Technology Transfer Needs

Numerous research and/or technology transfer needs and opportunities were identified (AAQTF, 2000). In brief, these include:

- Develop accurate and broadly applicable emission concentrations, rates, and emission factors for PM, odor and specific odorants applicable to CAFOs;
- Define emission rates as a function of diurnal, seasonal, and climatic variations, as well as design and management practices;
- Develop effective, practical odor control technologies for confined animals, manure and wastewater treatment, and land application systems;
- Determine relationships among odor, odorants, particulates and airborne microbial species;
- Identify kinetic release mechanisms for odorants and odor from principal manure sources;
- Target the development of control technologies that will specifically address the odor/odorant kinetic release mechanisms;
- Develop practical ways, capable of widespread adoption, of reducing ammonia from CAFOs;
- Effectively transfer appropriate, economically viable technologies for odor control to producers;
- Develop innovative air treatment processes for confinement building exhausts or covered lagoon surfaces;
- Develop odor reduction treatments for application immediately prior to land application;
- Develop accurate standardized measurement technologies for odor, odorants of principal concern, and fine particulate, and ensure these systems become widely available for research and demonstration; this should include sensory, chemical-specific, and electronic measurement devices that are well-correlated with the human odor experience;
- Develop accurate dispersion models for odor, odorants, and PM appropriate to specific types of CAFOs, addressing the inherent problems of Gaussian models;
- Characterize air quality as a function of distance from large CAFOs;
- Implement cooperative industry/agency/university programs for scientific evaluation of new products for producers' consideration and adoption;
- Assess the importance of indoor air quality at CAFOs and devise ways to reduce exposure levels;
- Devise suitable acceptability criteria for community-level exposure to odor and specific associated gases;
- Assess potential relationships between emission constituents, concentrations, and potential health indicators, and devise appropriate mitigation strategies accordingly;
- Establish partnerships with health research organizations and centers, identify potential health concerns associated with CAFOs and proactively address any identified issues.

Programmatic, Industry, and Community Relationships: A Discussion

In summation, air quality agencies need to recognize that the U.S. excels and will continue to excel in animal agriculture. Industry consolidation is a response both to securing positions of high productivity and adjusting to widely-recognized and increasing environmental protection responsibilities. Producers need to recognize that those technologies that were optimized for water quality protection may now seem insufficient for protecting air quality, which tends to be even more regionalized in terms of problems and solutions. Margins of community acceptance that were present when animal feeding

operations were dispersed and small (by today's standards) with individual farmer ownership may no longer exist as operations grow by orders of magnitude and become more complex in structure. Nor will relatively straight-forward technologies for controlling water pollution likely be considered adequate for the more complex air quality issues. Fortunately, there are promising technologies either available or being developed that can significantly reduce emissions of odor, odorants, or dusts, as appropriate. None of these technologies are free or even especially cheap; but neither are alternative legal remedies. Partnerships among industry, agencies, universities, research and technology transfer institutions, and the public will be the best and longest-lasting means of abating CAFO air quality problems that exist in parts of the country or in isolated instances. The nation remains far under-invested in development of technologies to assess and abate air contaminants from CAFOs, and as such seems in danger of reacting inappropriately with policies that are far ahead of the science or industry's ability to adapt in a timely fashion.

A program of accelerated research, education, technical training, technology transfer, and financial assistance to cope with CAFO air quality problems is strongly recommended. The USDA Agricultural Air Quality Task Force, established under the 1996 Farm Bill, has a stake in designing and fostering the implementation of these proactive, progressive programs.

Executive Summary

<u>CAFO Air Quality Parameters: Odor and Odorants</u>

- CAFOs can affect air quality through emissions of odor, odorous gases (odorants), particulates (including biological particulate matter), volatile organic compounds and/or some of the so-called greenhouse gases.

- Odor from CAFO sources, as experienced by humans, is the composite of as many as 170 or more specific gases, present in trace concentrations either above or below their olfactory thresholds.

- The primary odorous gases of concern include ammonia and hydrogen sulfide. However, the importance of ammonia and hydrogen sulfide to downwind composite odor as perceived by neighbors is questionable or negligible.

- Field and laboratory research has largely focused on measuring concentrations of odor. Data on emission rates, flux rates and emission factors are needed to develop science-based policies for the reduction of CAFO odor and odorants.

- Future research should be directed toward determining those odorous gases that more closely correlate with odor as perceived by humans.

- Carbon dioxide, methane and non-methane reactive organic gases are natural products of manure decomposition. Strategies to reduce emissions of odor and odorants are likely to reduce emissions of these co-product gases.

<u>Emission Factors</u>

- Improved processes for updating emission factors for an array of CAFO-related air contaminants, such as PM_{10}, $PM_{2.5}$, volatile organic compounds and ammonia should be initiated and accelerated.

Human Response and Health Effects

- Concerns with health effects of odor, odorants, biological and other particulate matter from CAFOs include livestock, employees and neighbors. Recent evidence suggests greater secondary health effects on frequently exposed neighbors than previously documented.

Current Federal and State Policies

- Water quality concerns were first addressed in the Federal Water Pollution Control Act of 1972, which listed CAFOs as point sources. A patchwork of tailored policies and regulations has attempted to address voids of groundwater protection and nutrient management, and only in a few cases have air quality concerns been addressed.

Integrated Programs

- Integrated programs to address air quality from CAFOs have not been funded or developed. A collaboration of agencies is needed to work with issues associated with CAFOs and air quality, just as similar collaborative activities have succeeded in regard to water quality.

Odor Control Technologies

- There are four basic approaches to control odor and odorants: ration/diet manipulation, manure treatment, capture and treatment of emitted gases and enhanced dispersion. Each approach has multiple technologies that need to be tailored on a site-specific basis.

Dust Control Technologies

- Technologies for particulate (dust) control from open-lot feeding systems, where needed, include frequent manure removal, stocking density adjustment to take advantage of excreted manure moisture and water sprinkling.

Research Funding

- A program of accelerated research, education, technical training, technology transfer and financial assistance to address CAFO air quality problems is strongly recommended.
- USDA and EPA funding levels have not been adequate to address or solve air quality problems associated with CAFOs.
- *The AAQTF (2000) recommended at least $12.8 million per year for coordinated, integrated programs for animal agriculture, as part of the additional $65 million in total funding requested for agricultural air quality.*

References

AAQTF. 2000. Air Quality Research and Technology Transfer White Paper and Recommendations for Concentrated Animal Feeding Operations. Agricultural Air Quality Task Force, USDA Natural Resources Conservation Service, Washington, DC. 123p. http://www.nhq.nrcs.usda.gov/faca/Policies/CAFO.htm.

Amerman, C. R. 2001. Personal Communication. USDA-ARS, Beltsville, MD. February 5.

Hegg, R. O. 2001. Personal Communication. USDA-CSREES, Washington DC. February 4.

USEPA. 2001. National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitations Guidelines and Standards for Concentrated Animal Feeding Operations: Proposed Rule. U.S. Environmental Protection Agency, Washington, DC. 40 CFR Parts 122 and 412. Federal Register 66(9):2959-3008. January 12.