BEST MANAGEMENT PRACTICES (BMPs) FOR AMMONIA EMISSIONS REDUCTION FROM ANIMAL FEEDING OPERATIONS: A COLORADO CASE STUDY

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ABSTRACT

Ammonia emissions from agriculture are a growing concern, in particular, in Colorado where nitrogen deposition in Rocky Mountain National Park has highlighted public concerns. Due to the high level of political pressure on agriculture to reduce its emissions, the agricultural community in Colorado has recently developed a Rocky Mountain National Park Ag Strategy for decreasing ammonia emissions from agriculture and nitrogen deposition in the park. The strategy includes the completion of a thorough literature review on Best Management Practices (BMPs) for ammonia reduction and evaluation of the efficacy and cost of the most promising BMPs on local feedlots and dairies. In addition, a survey will be completed to evaluate producer attitudes and understanding of the ammonia issue, as well as current levels of ammonia BMP adoption, and constraints to increased BMP adoption. The strategy also includes education and outreach functions including the development of a BMP factsheet series, photo gallery of ammonia BMPs, and a decision tree to aide producer decision-making regarding ammonia BMPs. These components will be available to producers and their consultants through a website. Our goal is to minimize the negative human health and environmental impacts of ammonia emissions from agriculture through the adoption of field-tested, effective, and economical BMPs on Colorado's feedlots and dairies.

INTRODUCTION

Globally, agriculture is the largest source of atmospheric ammonia, with animal agriculture accounting for approximately 40% of total emissions, and crop agriculture contributing an additional 23% from synthetic fertilizer application and crop emissions (Bowman et al., 1997). Ammonia is produced on livestock operations when urea nitrogen in urine combines with the urease enzyme in feces and rapidly hydrolyzes to form ammonia gas. The reaction is quick, taking anywhere from 2-10 hours for ammonia volatilization to peak after mixing of urine and feces (Muck, 1981; James et al., 1999). The quantity and rate of ammonia volatilization depends on a variety of factors such as the amount of crude protein in feed rations, manure management strategies, pH, and climate effects (temperature, relative humidity, etc.), to name a few. Since there is such a large reservoir of ammonia sources (i.e. manure) on livestock operations, there is no shortage of ammonia volatilization potential.

In the summer months, downwind ammonia emissions from a dairy can reach up to 30 parts per million (ppm) (Marcillac et al., 2006), while source emissions (i.e barns, drylots, and

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lagoons) can be much higher, reaching levels of over 200 ppm in heavily manured areas. High concentrations such as these affect both human and animal health as well as atmospheric visibility. When in gaseous form, ammonia has a short atmospheric lifetime of about 24 hours and usually deposits near its source, contributing to eutrophication of surface waters and changes in ecosystems (Krupa, 2003). Since ammonia is one of the only basic species in the atmosphere, it readily reacts with strong acidic species in the atmosphere such as nitric and sulfuric acids, which are byproducts of the combustion process of motorized vehicles and industrial production, to form ammonium salts, also known as fine particulate matter or $PM_{2.5}$. Due to their small diameter (less than 2.5 µm) and increased atmospheric lifetime of 15 days, these particulates are able to travel long distances before being dry or wet deposited to the ground surface. This allows them to travel from rural areas to urban locations where they mix and build up in the atmosphere leading to smog and human respiratory issues.

POLITICAL ACTION

In response to a high level of concern among citizens living near Rocky Mountain National Park (RMOC), the Colorado Air Quality Control Commission formed a RMNP sub-committee in 2005 to evaluate sources of N deposition and to develop potential solutions. The Colorado Department of Public Health and Environment (CDPHE) completed an ammonia inventory to identify the primary sources of ammonia in the state of Colorado. The CDPHE found that when non-regulatable sources of ammonia (such as wildlife, native soils, and human perspiration) were removed from the inventory, agricultural contributions amounted to approximately 60% of statewide ammonia emissions with 40% from animal agriculture and 20% from fertilizer use.

The inventory results led to discussion of the potential for regulation of ammonia emissions from agriculture in the state. A RMNP Ag Team was formed for the purpose of the development of an Ag Strategy. The Ag Team is composed of representatives of the Colorado Livestock Association, Colorado Farm Bureau, Rocky Mountain Farmers Union, Colorado Dairy Farmers, Colorado Corn Growers Association, Rocky Mountain Agri-Business Association, Colorado Department of Agriculture, Colorado Department of Public Health and Environment, Environmental Protection Agency, Environmental Defense, Colorado State University, and others. The Ag Strategy has been developed around four cornerstones—1) research into ammonia Best Management Practice (BMP) adoption, effectiveness, and cost; 2) gaps in the ammonia emissions inventory; 3) air quality modeling; and 4) education and outreach. Colorado State University is leading the research and outreach aspects of the RMNP Ag Strategy.

The Ag Strategy will be finalized in February 2007, and the Air Quality Control Commission will meet to discuss and evaluate the Ag Strategy as part of the RMNP Comprehensive Strategy.

BMP RESEARCH AND DEMONSTRATION

A thorough literature review has been completed in order to identify the most promising BMPs for reduction of ammonia emissions from agriculture. The most promising BMPs include:

Ammonia BMPs for Nutrition and Animal Management:

- Reduce the amount of crude protein in the diet to match the animal's needs (Smits et al., 1995; Frank and Swensson, 2002; Rotz, 2004; Todd et al., 2006).
- Practice phase feeding.
- Feed an ideal protein to monogastric animals.
- Practice oscillating protein feeding for ruminants (Cole, 1999).

- Increase animal efficiency (e.g. genetic selection, feed additives, etc.)(Dunlap et al., 2000).
- Proper building ventilation to improve animal health by removing toxic emissions from the air (Zhang et al., 2005).

Ammonia BMPs for Barns:

- Flush freestall barns and alleyways regularly with clean or recycled water (Kroodsma et al., 1993; Braam et al., 1997).
- Use sand bedding in dairy freestalls (Misselbrook and Powell, 2005).
- Provide adequate ventilation in barns to ventilate and cool buildings (Hinz and Linke, 1998).
- Scrub exit air from barns (Hilhorst et al., 2002).

Ammonia BMPs for Drylots:

- Scrape manure in pens frequently.
- Provide shade for cattle in open lots to encourage movement throughout the pens over the course of the day to disperse manure over the pen surface (Armstrong, 1994; White et al., 2001).

Ammonia BMPs for pastures:

- Stock only the appropriate number of animals on pasture to avoid overgrazing pastures.
- Move water and feeding areas on a regular basis to spread urine and feces deposits over the field (White et al., 2001).
- Irrigating may reduce ammonia emissions immediately after grazing, but could increase emissions of nitrous oxide and groundwater contamination with nitrate (Rotz, 2004).

Ammonia BMPs for Waste Management:

- Confine recycled waste water used for flushing barns and alleyways (Hartung and Phillips, 1994).
- Cover lagoon or allow a natural crust to form on top of the lagoon surface (Rotz, 2004; Misselbrook et al., 2005).
- Manage solid separation so it maximizes the removal of solids from waste influent (Zhang and Zhu, 2003).
- Aerate or circulate the lagoon surface (Sneath et al., 1992; Yang and Wang, 1999; Heber et al., 2002; Rumburg et al., 2004; Zhang and Zhu, 2005).

Ammonia BMP for liquid, slurry, and solid manure application:

- Manure application should occur during cool weather and on still rather than windy days whenever possible (Amon et al., 2006).
- Following agronomic rate recommendations, apply liquid slurry onto soil surface as quickly as possible to minimize storage time and maximize soil infiltration which reduces volatilization (Amon et al., 2006).
- Digested slurry and liquid manure should be applied to soils during cool weather with low trajectory such as drop nozzles for liquid slurry. Minimize liquid manure application by broadcast sprinkler irrigation (Rotz, 2004).
- Avoid broadcast spreading of manure on grasslands or soils with crop residues. Instead band slurry in established crops when possible (Rotz, 2004).
- Inject liquid or slurry manure to an appropriate root depth when soil moisture is favorable to minimize volatilization (Rotz, 2004; Rodhe et al., 2006).

- Incorporate manure into the soil as soon after application as possible to reduce the air surface exposure time (Malgeryd, 1998; Sommer and Hutchings, 2001).
- Analyze manure and soil prior to application to match application rates with crop requirements and soil type (Waskom and Davis, 1999).
- If possible, time manure application to reduce nitrogen loss by feeding plants when the nutrients are in demand. This practice is limited to liquid manures, as solids are harder to control due to mineralization (Van Horn et al., 1996; McGechan and Wu, 1998).

The most promising BMPs will be demonstrated on 12 feedlots and dairies in Colorado in 2007 and 2008. The BMPs will be evaluated for their effectiveness in reducing ammonia emissions and their implementation costs. In addition, a survey will be sent to feedlot and dairy operators in Colorado, Nebraska, and Iowa in February 2007 regarding their knowledge of the ammonia issue, current ammonia BMP adoption rates, and producer constraints to adoption. Preliminary survey results will be incorporated into the final proceedings paper.

EDUCATION AND OUTREACH

An outreach strategy was developed in December 2006 as part of the RMNP Ag Strategy. In 2006, presentations were made to Colorado Farm Bureau, the Rocky Mountain Agribusiness Association, and Certified Crop Advisors regarding ammonia impacts on human health and the environment and possible BMPs for reduction of ammonia emissions. In the future, presentations will be made to each of the Colorado Livestock Association's Council meetings (Feeder Council, Dairy Council, and Swine Council) and to the Colorado Corn Growers Association.

In 2006, a dairy-specific factsheet was written and published in Colorado Dairy News (Davis, 2006) on ammonia reduction BMPs. In the future, we will develop an online factsheet series including photos from the BMP demonstration sites and a decision tree to aide producers in selecting optimum BMPs for their operation. The factsheets, BMP photo gallery, and decision tree will all be accessible on a new website linked from www.manuremanagement.info. We will announce the availability of the website and its components through our regular monthly article in the Colorado Livestock Association's Friday Facts newsletter.

CONCLUSION

Agricultural ammonia emissions have important impacts on both human health and the environment, in particular, due to N deposition in Rocky Mountain National Park. Our goal is to minimize these impacts through the adoption of field-tested, effective, and economical BMPs on Colorado's feedlots and dairies.

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