Agriculture -- Ammonia Emissions and $PM_{2.5}$

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Ammonia

Environmental and Health Impacts

Although not listed as one of EPA's six regulated criteria air pollutants, ammonia also impacts our environment. Ammonia (NH_3) volatilizes easily and is quickly converted to aerosols or subjected to deposition processes. Ammonia deposition results in eutrophication, acid rain, and negatively impacts biodiversity.

When atmospheric NH_3 reacts with NO_X (a by-product of combustion) it forms ammonium nitrate, one of the leading sources of $PM_{2.5}$ which impacts human health. Particulate matter that is smaller than 2.5µm ($PM_{2.5}$) travels deep into the lungs, lodges there, and damages the respiratory system. $PM_{2.5}$ is regulated by the U.S. EPA as one of the six criteria air pollutants.

Rate of Ammonia Emissions

Accurately estimating NH_3 emissions is complicated and difficult. Ammonia volatilization is impacted by many chemical and biological processes which result in large variations due to geographic region, season, time of day, moisture content, cropping system, management practices, field variability, and more. Because NH_3 emissions are highly variable and difficult to measure, there is large uncertainty associated with the modeling, transport and reactivity of atmospheric NH_3. This results in large differences in NH_3 emission estimates.

Ammonia Emissions and Agriculture

Agriculture's Role

Agriculture is one of the leading sources of atmospheric NH_3. On a global scale, agriculture produces approximately half of all atmospheric NH_3, with livestock producing about 40% of total NH_3 emissions, and crop production about 12% (Aneja et al., 2007).

In the United States, it is estimated that 60-85% of the total NH_3 emissions come from agricultural sources (USDA, 2014). Of the agricultural NH_3 emissions, about 2/3 come from livestock production, and 1/3 from crop production (Bauer et al., 2016).

Ammonia Emissions from Livestock

Ammonia emissions from livestock primarily come from excess protein (nitrogen) fed in the diet. Any nitrogen not utilized for maintenance, growth, or milk production is excreted in the urine and feces. Cows excrete up to 90% of the nitrogen they eat, while pigs excrete about 70% (Meadows, 2016). The nitrogen in animal manure is converted to NH_3 by hydrolysis, mineralization, and volatilization processes.

Over half of the nitrogen in manure is in the form of NH_3 which can easily volatilize and enter the atmosphere (Herbert et al., 2009). Some of the factors influencing the rate of NH_3 emissions from manure are housing/flooring, diet, temperature, and the type of manure storage system.

Urine is primarily made up of urea, which is rapidly converted to NH_3 by the enzyme, urease. Urease is primarily found in the feces. Separating urine and feces can reduce NH_3 emissions.

Ammonia Emissions from Crops

Inorganic nitrogen (N) fertilizer, a product of the Haber-Bosch process, is also a significant contributor of NH_3 emissions. The use of inorganic N fertilizer over the past 70 years has doubled crop production yields and enabled a concurrent expansion in livestock production. Ammonia emissions have also doubled during this time (Roser and Ritchie, 2020; Stewart et al., 2005). As the world population continues to grow, it is anticipated that fertilizer use will continue to expand which will, in turn, increase NH_3 emissions.

Particulate Matter ($PM_{2.5}$)

Vehicles

Agriculture is not the only important source of NH_3 in the US. Combustion from vehicles and industrial stacks are also significant sources of NO_X and NH_3. In urban areas, where 40% of our population resides, NH_3 emissions from vehicles are greater than agricultural emissions. Over the past decades, NO_X emissions have been decreasing, whereas NH_3 emissions have been slowly increasing (Figure 1).

Emissions of NH_3 from motor vehicles and industrial stacks is largely a byproduct of NO_X control technologies. In general, control technologies result in a trade-off -- as we reduce NO_X emissions, we increase NH_3 emissions.

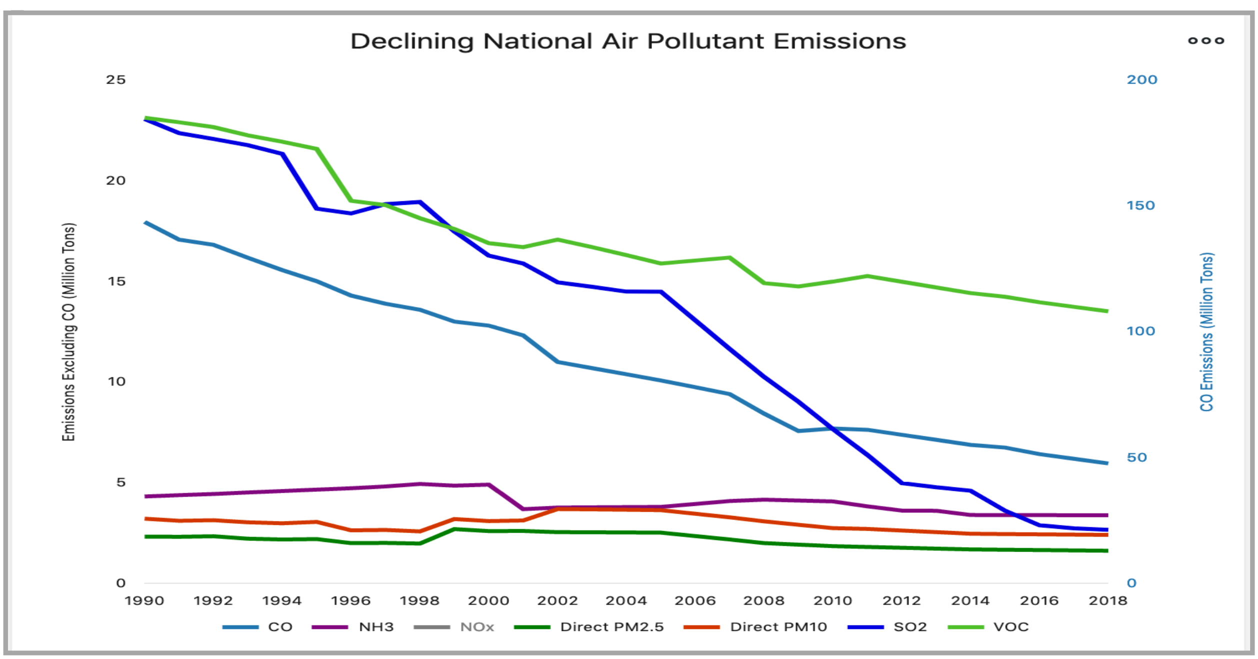

Figure 1. Air Pollutant Emissions. Source: US EPA Our Nation's Air (2019b).

Reducing $PM_{2.5}$

Present-day sensitivity studies show that at a national level, a reduction in either NO_X or agricultural NH_3 will lead to reduced $PM_{2.5}$ pollution; however, this can vary by area. In many agricultural areas, atmospheric NH_3 concentrations are significantly higher than NO_X concentrations. For example, in Cache Valley atmospheric NH_3 concentrations are 2-3 times greater than NO_X concentrations. Implementation of controls that cut NH_3 emissions in half in Cache Valley would have no impact on $PM_{2.5}$ levels. California is in a similar situation. Both states are regulating the limiting factor (NO_X) to reduce $PM_{2.5}$.

In general, control measures for NO_X emissions are easier to implement than NH_3 controls. NO_X emissions primarily come out of tailpipes, or stationary sources; whereas, NH_3 emissions from agriculture are often diffuse (e.g., soil emissions). According to the EPA, combustion and mobile sources produce the majority of NO_X emissions. Agriculture produces approximately 8.5% of total NO_X emissions (EPA, 2019a).

Ammonia Mitigation Techniques in Agriculture

Agricultural Ammonia Mitigation Techniques

There are several practices that can help reduce NH_3 emissions from agriculture. Adoption of these techniques is often limited due to the expense, short-term effectiveness resulting in a need for repeated applications, or the infrastructure required.

Diet Manipulation:

- Balancing diets to provide the essential amino acids while limiting protein overload can reduce N excretion by 40% (Meadows, 2016).
- Feed additives such as tannins, zeolite, and charcoal can bind with the N, reducing ammonia emissions.

Housing/Floor Surfaces:

- Covered structures have lower NH_3 emissions than open feedlots. This is primarily due to a reduction in wind speed and drying.
- Frequent removal of manure. Smooth floor surfaces aid in manure removal.
- Flushing – ammonia is highly soluble in water resulting in a decrease in NH_3 emissions.

Filters/Scrubbers:

- Biofilters use microbial action in an aerobic environment to oxidize the reduced compounds. Exhaust air is passed through the filter media (e.g., wood chips, compost, soil, etc.) to bind NH_3.
- Gas absorbers/scrubbers pass exhaust air through an enclosed tower with absorption media flowing counter-current to the incoming air.

Manure Additives:

- Acidification of manure – e.g., phosphoric acid in poultry systems. Ammonia emissions are reduced at lower pH.
- Zeolite, Carbon source – binds N, reducing NH_3 emissions.

Manure Storage:

- Covered lagoons – Permanent covers (e.g., plastic, concrete), floating covers (e.g., polystyrene, rubber), and biocovers (e.g., chopped straw).
- Oxidation of liquid manures – aeration, chemical oxidants (e.g., potassium permanganate, hydrogen peroxide), biological treatments.
- Carbon source – the addition of a carbon source such as straw or saw dust to solid manure enhances microbial binding of N and reduces NH_3 emissions.

Composting:

- The magnitude of NH_3 emissions during manure composting depends on the ratio of C:N. Without the addition of supplemental C carbon sources, NH_3 emissions during manure composting are high.

Land Application:

- Injection – inject slurry and liquid manures 4-8" deep in soil.
- Incorporation – incorporate solid manure within 24 hours after application. Majority of NH_3 emissions occur within first 72 hours.

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