

# Understanding NH<sub>3</sub> Emission and the Environmental and Health Impacts

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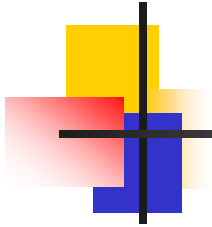
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# Outline

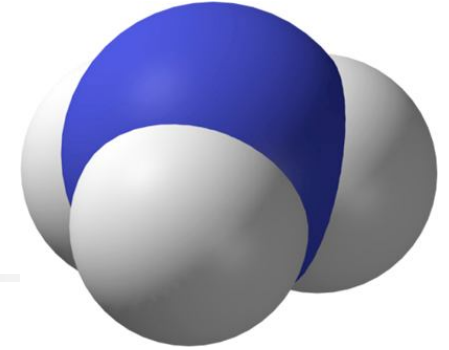
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- What is ammonia ( $\text{NH}_3$ )?
- How and where it is generated?
- Why do we care about it?
- Its health impacts
- Its environmental impacts
- Nitrogen conservation needs
- Summary



# What is Ammonia (NH<sub>3</sub>)?

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- A gas (NH<sub>3</sub>), colorless, light than air, highly soluble in water, and has a sharp pungent odor detectable at 5 - 18 ppm.
- Ammonia has two forms, gas phase and liquid or solid ammonium phase.
- one of the important forms of nitrogen (NH<sub>3</sub>, NH<sub>4</sub><sup>+</sup>, NO<sub>3</sub><sup>-</sup>, NO<sub>2</sub><sup>-</sup>, N<sub>2</sub>O, NO<sub>x</sub> and atmospheric N<sub>2</sub>) participating in the nitrogen cycle.
- Reacts with gaseous nitrate and sulfate for form fine particles.
- used for the production of fertilizers, nitric acids, fuels, explosives, and refrigerants;



# Ammonia Gas and Ammonium

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Ammonia easily convert from gaseous phase to liquid and solid phase ammonium ( $\text{NH}_4^+$ ) as pH changes.



- pH=9.25 (>7)
  - ★ 50% as un-ionized ( $\text{NH}_3$ )
  - ★ 50% as ionized ( $\text{NH}_4^+$ )
- pH<7
  - ★ 99% as ionized ( $\text{NH}_4^+$ )



## How $\text{NH}_3$ is Generated?

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- ◆  $\text{NH}_3$  is generated because inefficient conversion of feed N to animal products resulted in N excretion in urine of pigs and cattle and in the uric acid of poultry.
- ◆ The fecal enzyme urease catalyzes the hydrolysis of urine urea to form ammonia gas.
- ◆ Aerobic decomposition of uric acid of poultry also form ammonia gas.
- ◆ Mineralization of undigested protein generate also result in ammonia gas emission



# How NH<sub>3</sub> is Generated (cont)?

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- ★ Urine (swine and cattle)

- Urea hydrolysis



- ★ Uric acid (poultry)

- Aerobic decomposition of uric acid



- ★ Undigested protein

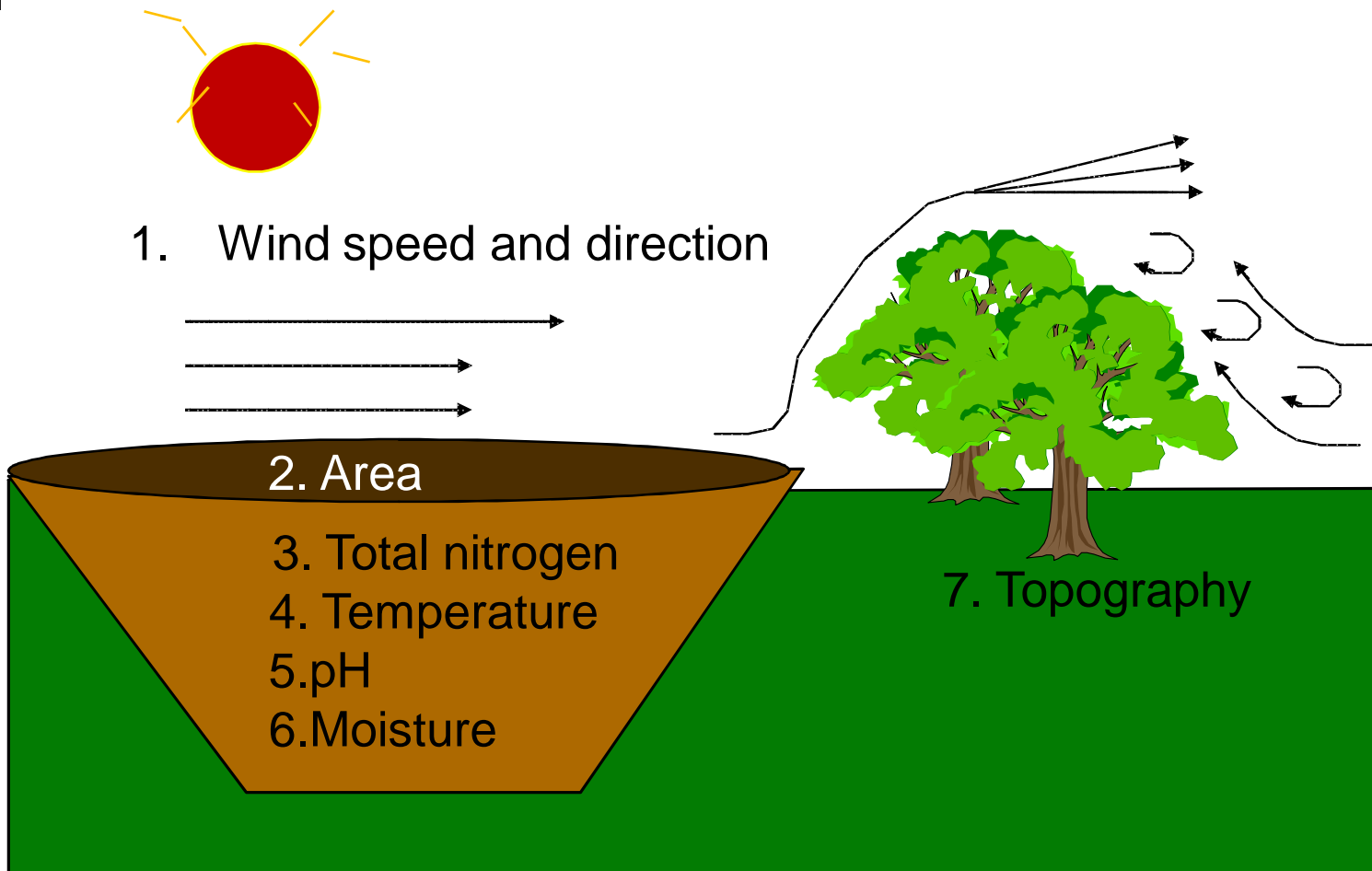
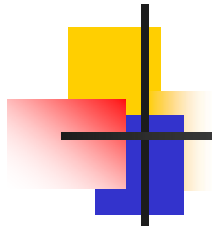
- Mineralization → NH<sub>3</sub>

# Sources of NH<sub>3</sub> Emission

- Manure and other organic mater on farms
  - ★ Animal buildings
  - ★ Manure storages
  - ★ Land application of manure



# Factors affecting NH<sub>3</sub> Generation and Dispersion







# Factors Affecting NH<sub>3</sub> Emission

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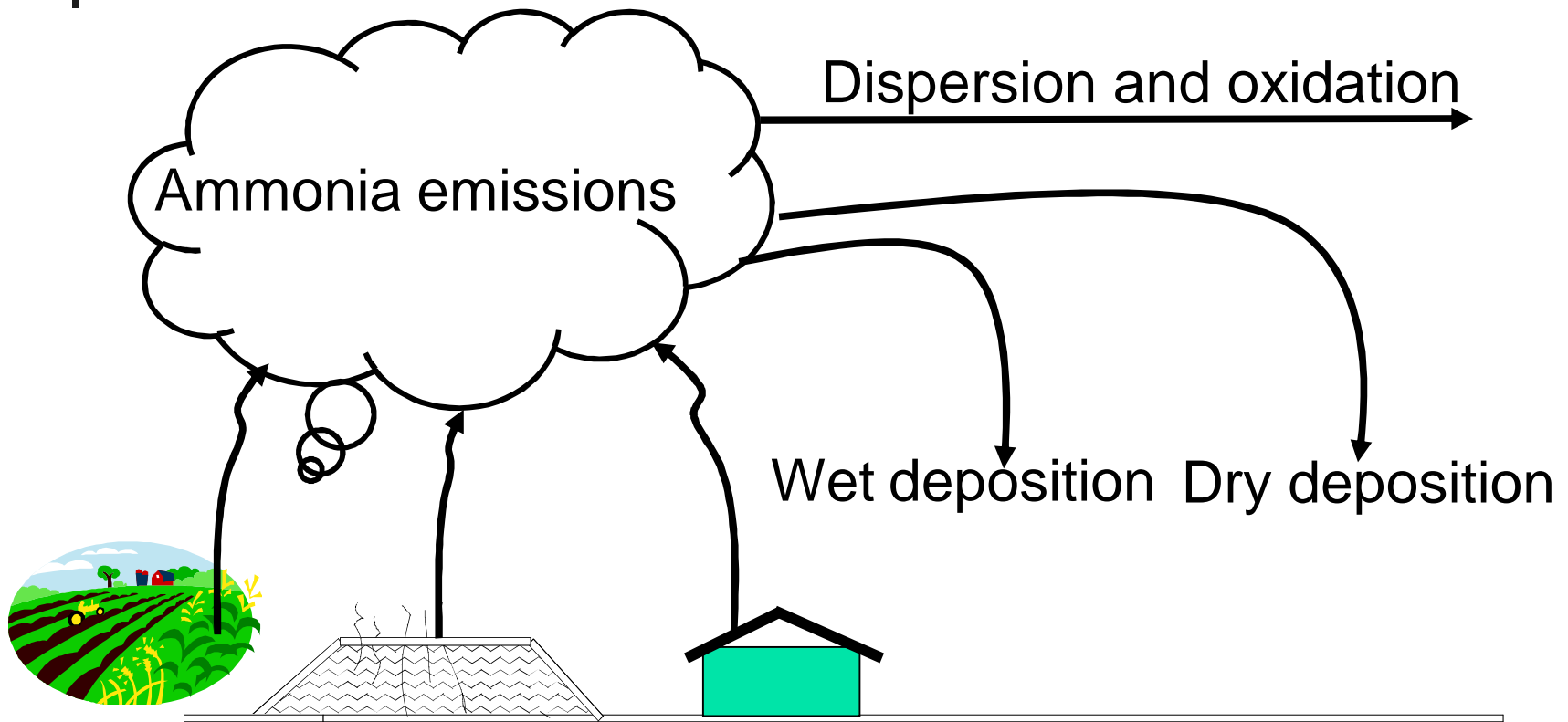
- Dietary Factors

- ★ Excess crude protein in diet
- ★ Low conversion of dietary N to animal products

- Environmental Factors

- ★ Total nitrogen content
- ★ pH
- ★ Temperature
- ★ Moisture content
- ★ Chemical and microbiological activities
- ★ Diffusive and convective transport in the manure
- ★ Ammonia concentration of air
- ★ Wind speed and air temperature

# Fate and Transport of NH<sub>3</sub>



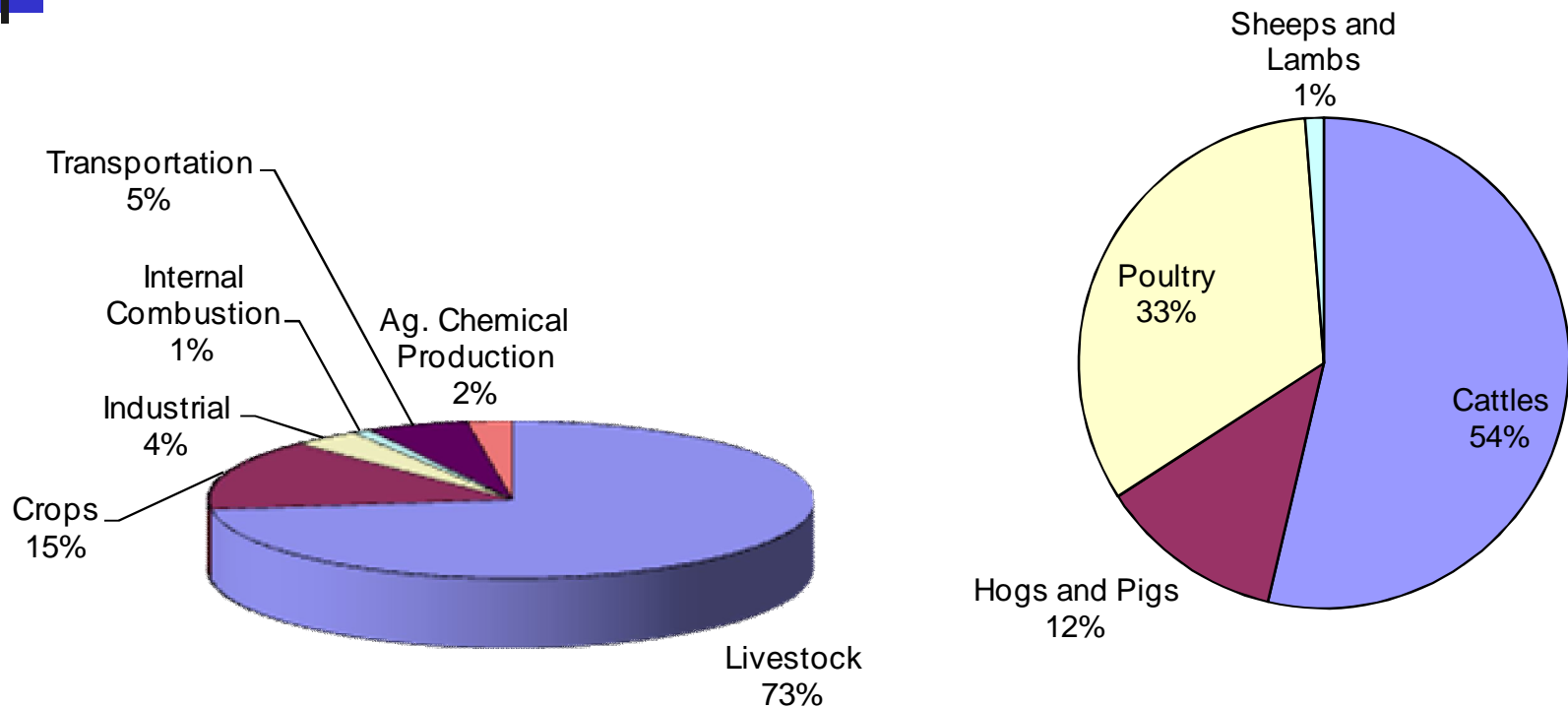


# Fate and Transport of $\text{NH}_3$ Cont...

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- ★ After released from the sources, ammonia will disperse vertically and horizontally in the atmosphere.
- ★ Dry and wet deposition will happen near the sources.
- ★ It has a lifetime of 1-5 days in the atmosphere.
- ★ Chemical reactions with other chemicals in the atmosphere form fine particles.
- ★ When is converted to  $\text{NH}_4^+$  aerosols, the lifetime increases up to 15 days.

# Why Do We Care about it?



<sup>1</sup> <http://pubwiki.extension.org/mediawiki/files/7/70/08junPPmartin.pdf>

<sup>2</sup> USEPA, 2002. [http://www.epa.gov/ttn/chief/ap42/ch09/related/nh3inventorydraft\\_jan2004.pdf](http://www.epa.gov/ttn/chief/ap42/ch09/related/nh3inventorydraft_jan2004.pdf)



# Its Human Health Impacts

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- Health Impacts

- ★ As a is a strong and corrosive irritant, ammonia injures and burns the wet tissue, such as eyes, nose, throat, and respiratory tract
- ★ Uptake of oxygen, decrease oxygenation of tissues and decrease metabolic function

- Health Consequences

- ★ Irritation to mucus tissues, increased rate of heart disease, pneumonia, asthma, and other respiratory issues



## Its Human health impacts (cont.)

The health effects of ammonia have been recognized through extensive literature.

Concentration (ppm)	Length of exposure	Health effects
50	< 24 hours	Slight, temporary eye and throat irritations and urge to cough
100	6 weeks	Irritation of eyes, nose, and throat
500	30 mins	Increased air intake into lungs, sore nose and throat
5000	< 30 mins	Kills quickly



# Health Impacts on Poultry

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- ★ At level of 10 ppm, trachea irritation was shown in turkeys.
- ★ At levels above 20 ppm, increased rate of infection of Newcastle disease was found.
- ★ At above 25 ppm, growth rate and feed conversion was impaired and the final body weight was reduced.
- ★ At levels of above 50 ppm, the birds are more susceptible to bacterial infections such as E. coli.
- ★ At above 100 ppm, the chick mortality was increased significantly.



# Health Impacts on Livestock

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- Swine

- ★ Reduce weight gain of 12-32% when exposed to 50-100 ppm ammonia levels
- ★ Lowered resistance to infectious diseases

- Cattle

- ★ Reduced lung function
- ★ Decreased mucociliary transport

Source: Randy Martin, eXtension webinar  
<http://www.extension.org/pages/55667/ammonia-the-air-water-interface>

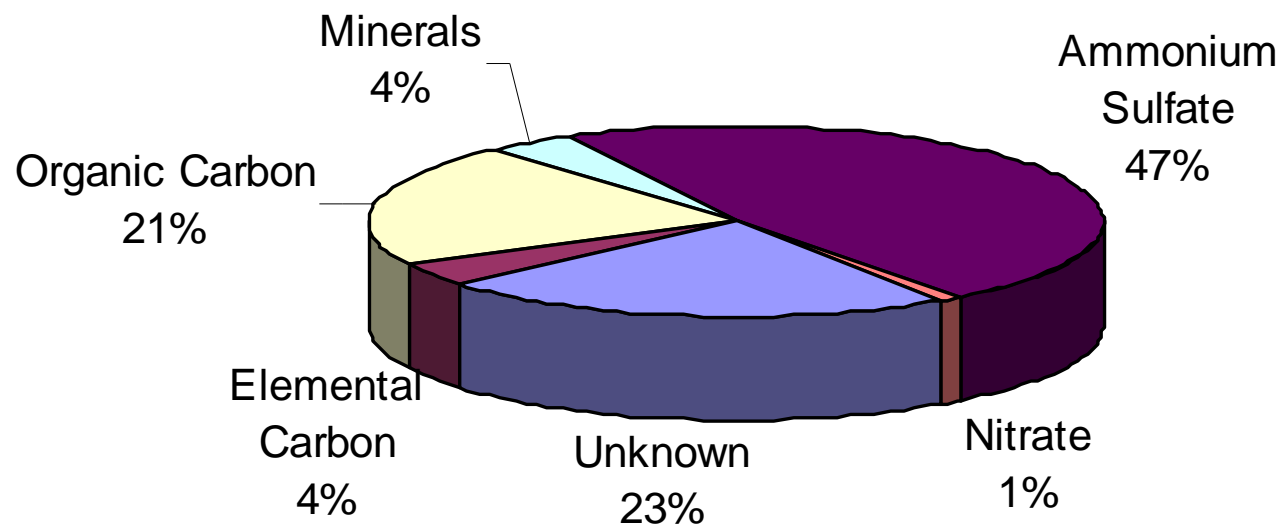


# NH<sub>3</sub> and Particulate Matter<sup>6</sup>

Ammonia gas can react with sulfuric and nitric acids in the atmosphere to form fine particles

- ◆  $\text{NH}_3(g) + \text{H}_2\text{SO}_4(g) \rightarrow \text{NH}_4\text{HSO}_4(g,l)$  (ammonium bisulfate)
- ◆  $\text{NH}_3(g) + \text{NH}_4\text{HSO}_4(g,l) \rightarrow (\text{NH}_4)_2\text{SO}_4(g,l)$  (ammonia sulfate)
- ◆  $\text{NH}_3(g) + \text{HNO}_3(g) \rightarrow \text{NH}_4\text{NO}_3(g,l)$  (ammonium nitrate)

# NH<sub>3</sub> and PM<sub>2.5</sub>



Source: Anderson N., R. Strader, and C. Davidson. 2003. Airborne reduced nitrogen: ammonia emissions from agriculture and other sources. *Environment International*. 29(2003): 277-286.



# Its Environmental Impacts Cont...

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- ◆ Ammonia deposition or wet deposition to the ecosystem leads to over-fertilization or eutrophication.
- ◆ The nutrient imbalance in the soil can be harmful to some crops while excessive nutrients in aquatic systems lead to decreased biological diversity;
- ◆ Ammonium sulfates deposited into soil and water systems can also get oxidized to form a mixture of nitric and sulfuric acids to cause ecosystem acidification.
- ★ Conversion to ammonium ion, and subsequently  $PM_{2.5}$ , its aerosol form, and eventual smog formation.



# Nitrogen Conservation Needs

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- According to the Fertilizer Institute, the U.S. consumed 10.4 million metric tons and imported 6.6 million metric tons of nitrogen fertilizer in 2001, which made it the largest importer of nitrogen fertilizers in the world.
- As the primary feedstock used in the production of nitrogen fertilizers, natural gas prices soared and so do ammonia nitrogen fertilizer.
- Since 1999, almost 40% of the U.S. nitrogen fertilizer capacity has been forced to permanently close due to the high cost of natural gas, which resulted in significant concerns about the availability and cost of nitrogen fertilizer for farming in the future.



# Summary Points Cont...

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- ◆ Inefficient conversion of feed N to animal products resulted in N excretion as ammonia.
- ◆ Manure and organic waste are main sources of ammonia on farms.
- ◆ Total nitrogen in manure, temperature, Ph, and mixture of urine and crease in feces affect ammonia generation. Air speed, temperature, moisture, and topography affect ammonia dispersion and transport
- ◆ High level of ammonia has significant health effects
- ◆ Ammonia emission is a pre-cursor of PM2.5 particle and cause ecosystem eutrophication and acidity.
- ◆ Conservation of nitrogen is needed for sustainability.

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