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Ammonia Mitigation Techniques for Agriculture

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Outline

- Ammonia generation mechanisms
- Sources of ammonia (NH_3)
- Control strategies
  - Animal housing
  - Manure storage
  - Manure application
- Conclusions

Nitrogen in Manure

- manures from different animal types can be very different
  - swine & bovine:
    - up to 97% of N excreted is in the form of urea in the urine
    - remainder as organic N in faeces
    - enzyme urease is only found in faeces
  - poultry:
    - 70% of N in the form of uric acid
    - remainder as organic N

Atai et al. (2005) & Ndegwa et al. (2008)

NH_3 Generation

- mineralization:

  undigested protein (bacterial degradation) → NH_3

- urea hydrolysis (urease enzyme):

  $$CO(NH_2)_2 + 2H_2O \rightarrow CO_2 + 2NH_3$$

- aerobic decomposition of uric acid:

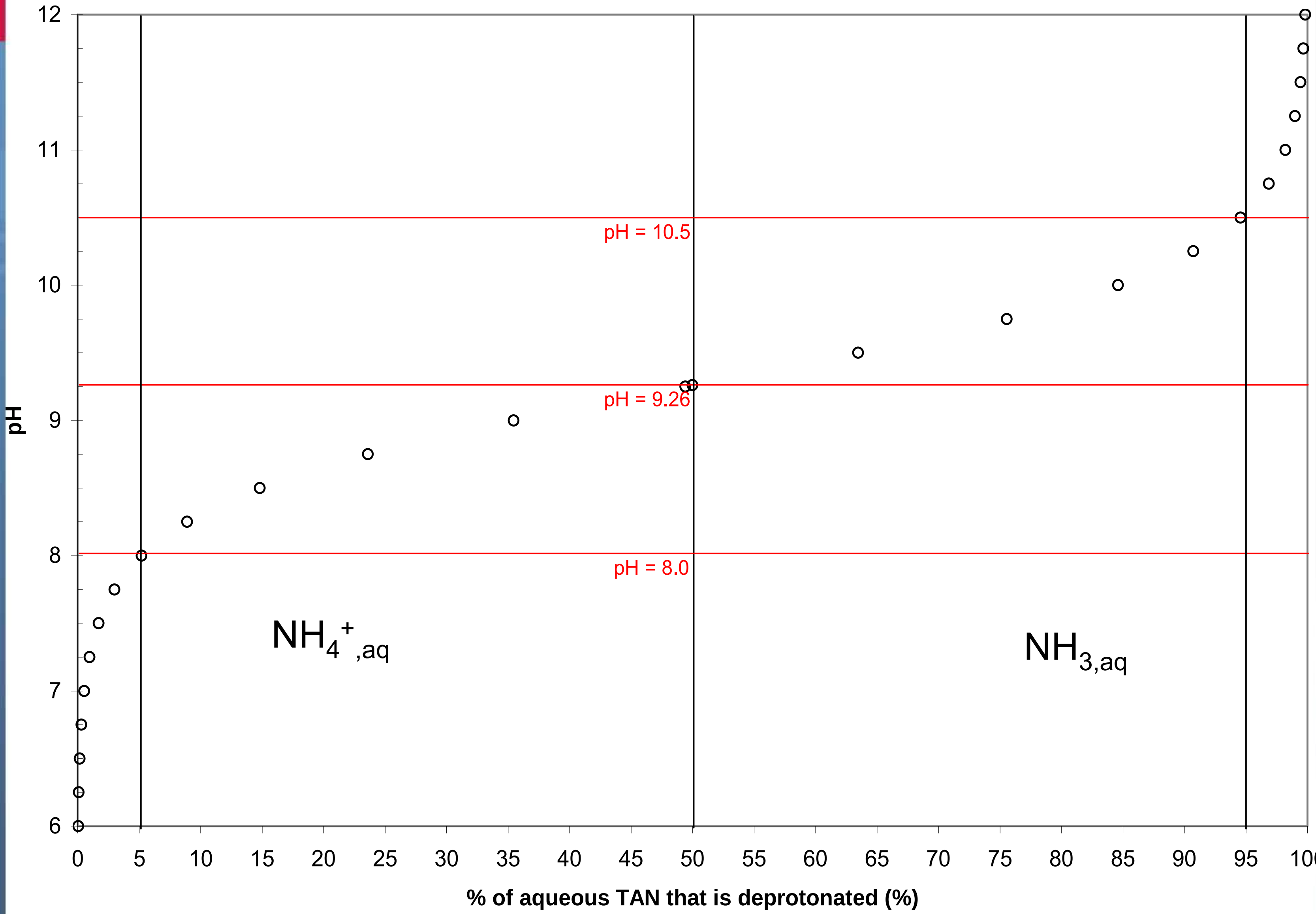
  $$C_5H_4O_3N_4 + 1.5O_2 + 4H_2O \rightarrow 5CO_2 + 4NH_3$$

Atia et al. (2005)

Ammonium vs. Ammonia

- in aqueous solution, can have both ammonium (NH_4^+) and ammonia (NH_3)
  - total ammoniacal nitrogen (TAN)
- NH_3 is the volatile component
- equilibrium between NH_4^+ & NH_3 is strongly pH dependent

Ammonium vs. Ammonia



Agricultural NH_3 Sources

- animal housing
- manure storage
- manure application
- fertilizer application
- other sources (i.e. composting)

OMAFRA Fact Sheet #720, 2006

Animal Housing

- Strategy: reduce crude protein levels in feed
  - for most animal, the higher the level of crude protein coming in, the higher the level of N excreted → higher NH_3 emissions
  - some success in shifting the excreted N from the urine to the faeces through increases in dietary fibre (pigs)
  - use of dietary supplements (zeolite, antibiotics, probiotics, vegetable oil, plant extracts, exogenous enzymes) have had varying success

Atai et al. (2005) & Ndegwa et al. (2008)

Animal Housing

- Strategy: immediate separation of urine and faeces
  - for swine & bovine
  - prevents the urease enzyme from coming in contact with the urea
  - may require modification to manure handling system (separate pits) and to the floor of the barn (urine drainage systems)
  - can get approximately 50% reduction in NH_3

Ndegwa et al. (2008)

Animal Housing

- Strategy: reduce air / manure contact
  - reduce the area of manure in contact with the air as well as the time of contact
    - more frequent scrapping and/or flushings
    - more effective with poultry than swine or bovine
  - for broilers and turkeys, re-use of litter results in increased ammonia emissions due to the N storage capacity of the litter

Atai et al. (2005) & Ndegwa et al. (2008)

Animal Housing

- Strategy: urease inhibitors
  - for swine & bovine
  - for mixed urine and faeces systems, addition of urease inhibitors can reduce ammonia production
    - cyclohexylphosphoric triamide (CHPT), phenyl phosphorodiamidate (PPDA) & N-(*n*-butyl) thiophosphoric triamide (NBPT)
    - requires weekly additions of inhibitors either in pit or feed yard
    - laboratory studies only - no actual case studies

Ndegwa et al. (2008)

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Animal Housing

- Strategy: addition of other “inhibitors” to manure or litter
  - buffers to reduce the pH of manure or litter
    - sulphuric acid, hydrochloric acid, phosphoric acid, alum, calcium chloride, Poultry Litter Treatment (PLT – sodium bisulfate)
  - ammonium binders
    - zeolite (highly selective of NH_4^+) – more effective in manure slurries and liquids than solid poultry manures
    - sphagnum moss & yucca plat extracts (saponins)
    - commercial products (Alliance®, De-Odorase®)

Ndegwa et al. (2008) & Roumeliotis & Van Heyst (2008)

Animal Housing

- Strategy: ammonia capture and control
  - biofiltration – ventilation fans exhausted to a biofilter where microbes treat the air
    - temperature, NH_3 concentration, substrate material, residence time, moisture in substrate
    - 9-100% efficient
  - scrubbing – water or acid spray
    - acid scrubbers ~40-100% effective
  - ozonation – rarely used in agriculture
    - 15-50% effective
  - oil sprinkling – 30% effective
  - electrostatic space charging system – some reduction in ammonia (S. Bittman)

Atai et al. (2005) & Ndegwa et al. (2008)

Manure Storage

- Strategy: enclose manure storage area
  - floating covers on manure pits
    - impermeable (PVC, foil, faom & plastic)
      - used with scrubbers or biofilters
    - permeable (straw, cornstalks, peat moss, foam, geotextiles, LECA®) – provide substrate for microbes to attach and transform the NH_3
    - surface crusting
    - % reduction ranges from 15% to 100%
  - prevent water infiltration

Atai et al. (2005), Ndegwa et al. (2008), & VanderZaag et al. (2008)

Manure Storage

- Strategy: temperature control
  - NH_3 volatilization increases with increases in temperature
    - reducing manure temperature from 15 °C to 10 °C can reduce NH_3 emissions by 40%
    - not always feasible

Manure Application

- Strategy: minimize time of manure exposure to atmosphere
  - direct injection (>75% effective)
  - surface placement by band spreading (trailing hose), shoes, and shallow slot injections (40-60% effective)
  - reduce time between surface spreading and incorporation
  - dilution with water to increase infiltration
  - cultivation of soil prior to application (increases soil porosity)

Atai et al. (2005) & Ndegwa et al. (2008)

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Manure Application

- Strategy: favourable weather effects
  - NH_3 emissions increase with temperature and wind speed – periods of cooler temperatures with calm winds better
  - manure infiltration greater with low soil moisture content

Atai et al. (2005) & Ndegwa et al. (2008)

Conclusions

- many control strategies exist from the barn to the field
- most have a cost associated with them although some involve changing management strategies
- not always clear if cost is recuperated in animal health and performance in a cleaner indoor barn environment or in a higher quality soil fertilizer
- most of the strategies look at the effect on NH_3 only
  - do not address synergistic or negative effects on other pollutants such as odour, particulate matter, methane, N_2O, etc.