Ammonia volatilisation from livestock slurries and mineral fertilizers

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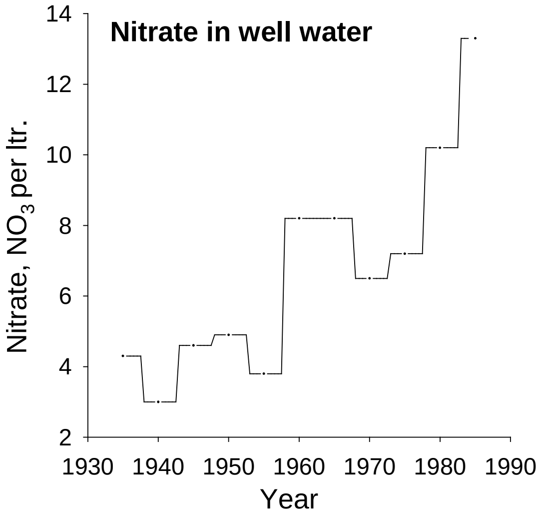
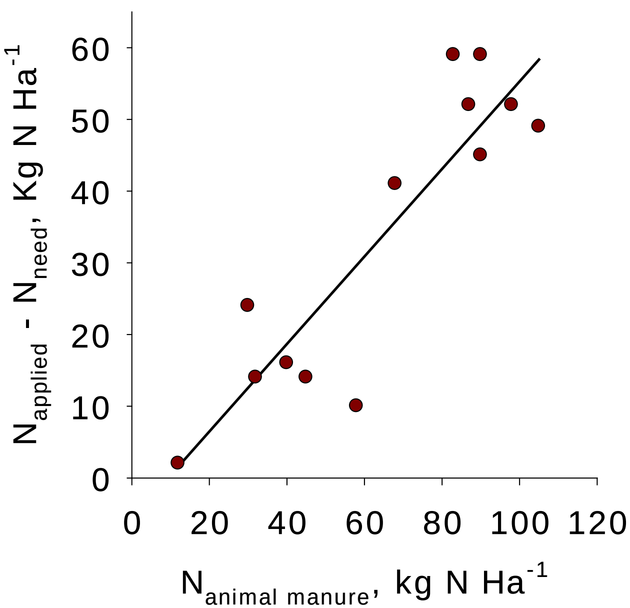
Nitrogen, Phosphorus and Oxygen NPO-decade

(Overgård 1982; Sommer 1982)





- Nitrate bomb
- Blue babies
- NPO was the front runner of the Action Plan for the Aquatic
- Environment I to III (APAE-I-III, Vandmiljøhandlingsplaner).

Ammonium in rainwater

(Sommer, 1984 & 2013). Idea for this work was provided by Eivind Hansen, Head of Centre for Terrestrial Ecology

- Acidification and eutrophication of natural ecosystems
- Airborne particulates that is a
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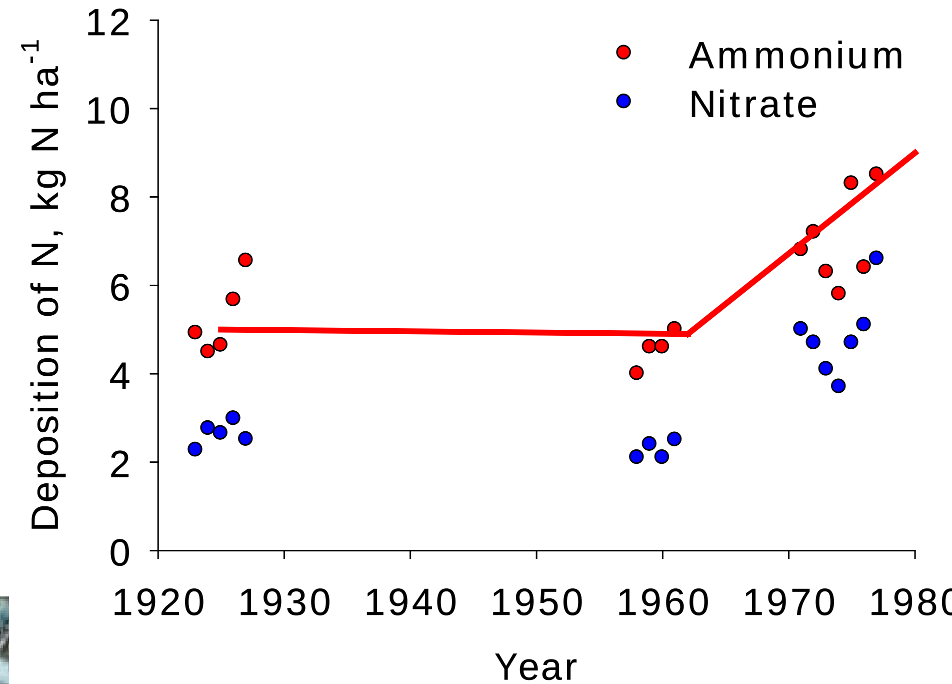
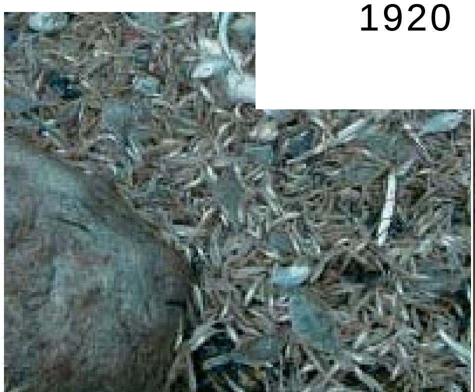
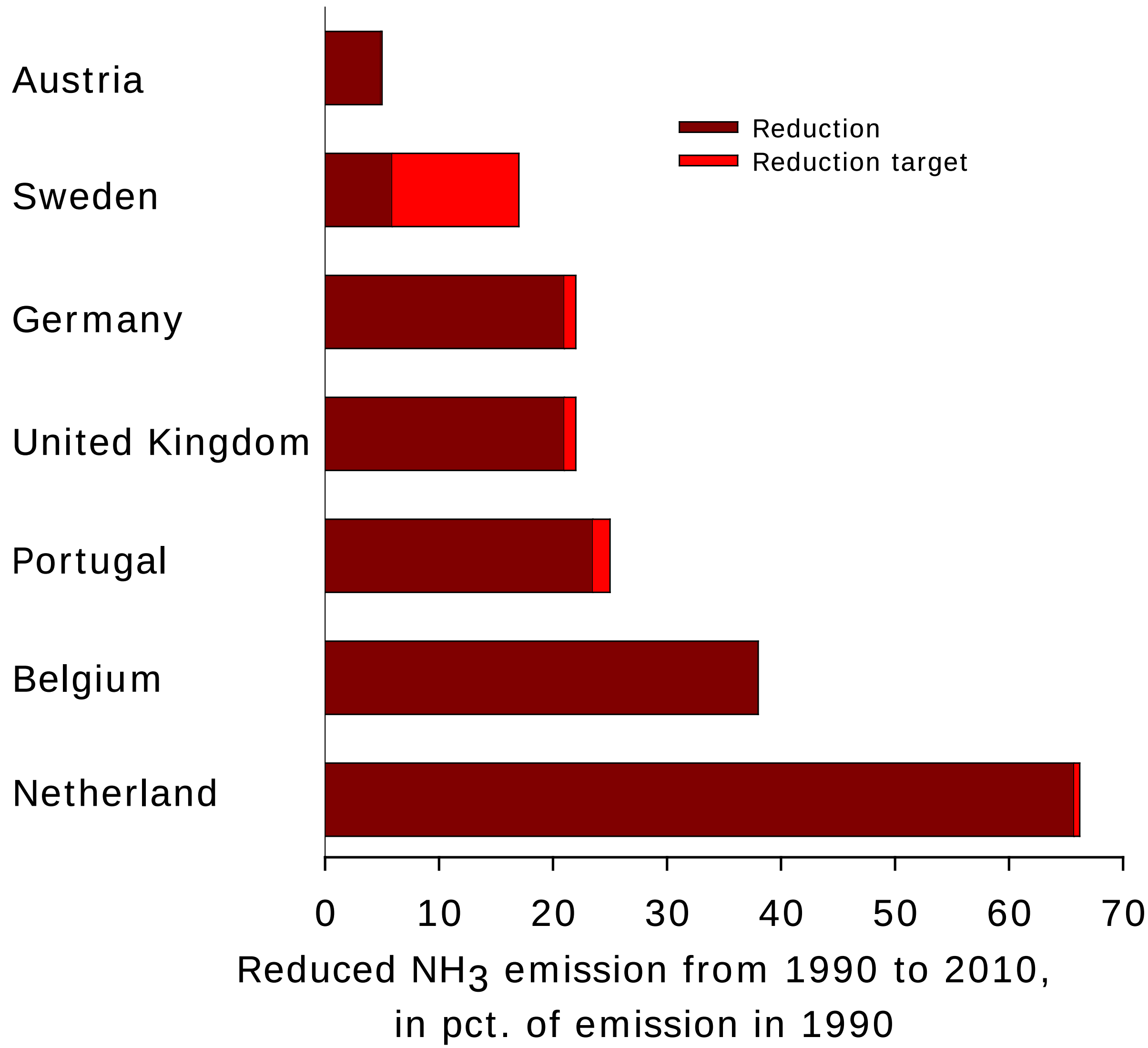
o the emission of NH3

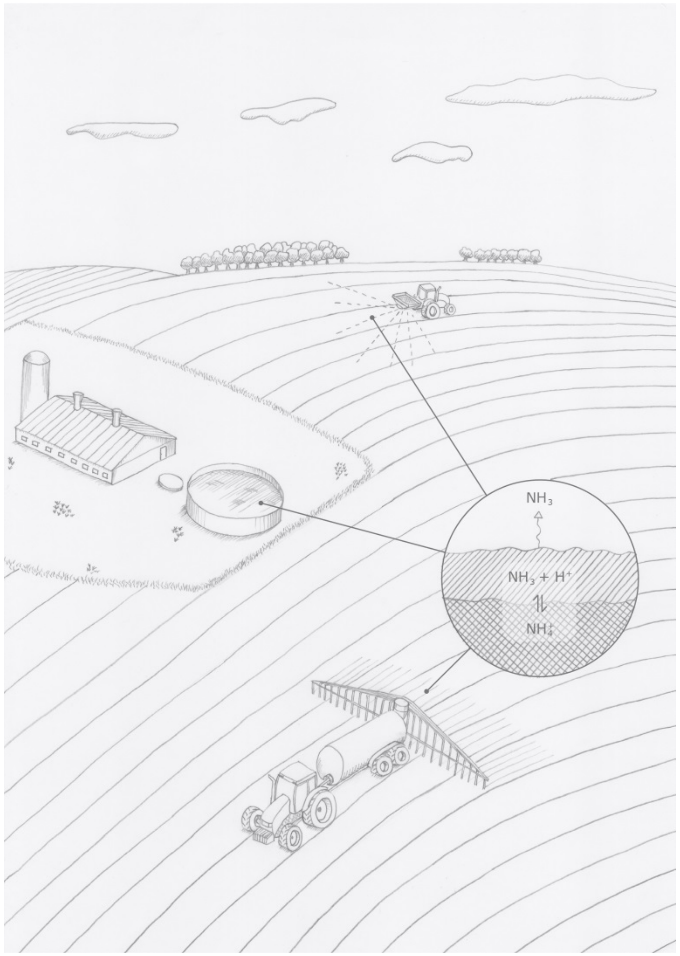




Example of EU regulations the Gothenborg protocol deals with ammonia



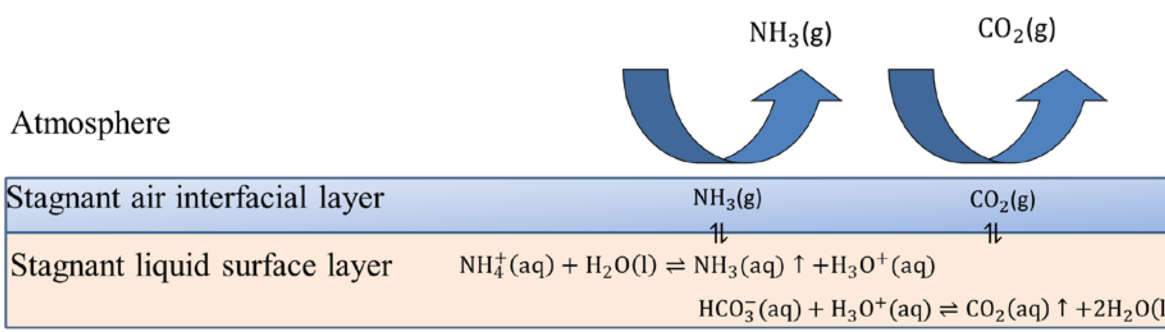
Ammonia emission - processes



From:

- Stored slurry
- Slurry applied in the field
- Mineral fertilizer in the field

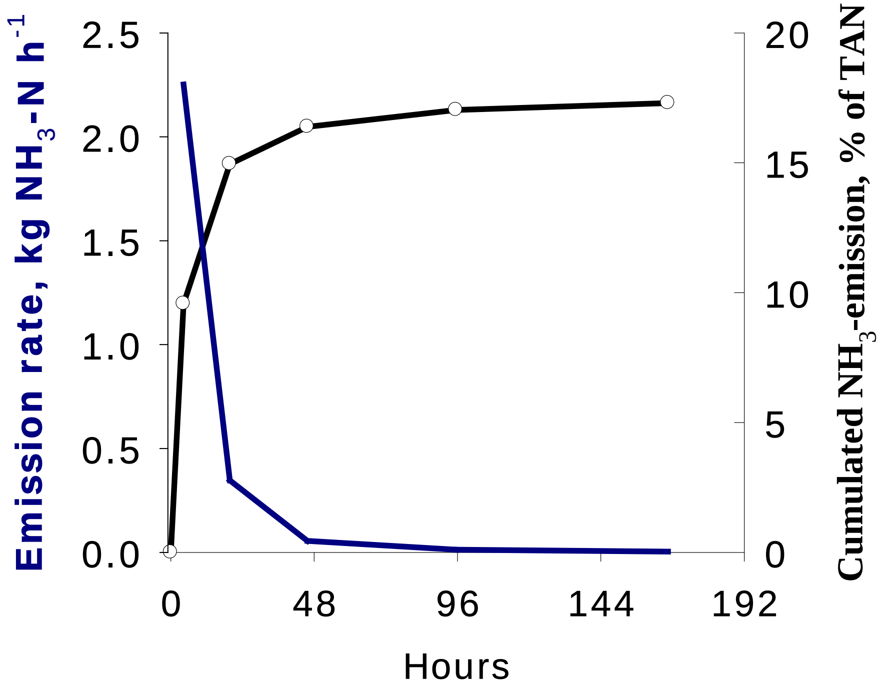
They have the release and emission processes in common



$$[TAN] = [NH_4^+(aq)] + [NH_3(aq)]$$

$$NH_3(aq) = \frac{TAN(aq)}{1 + (H_3O)^+ / K_N(Temp)}$$

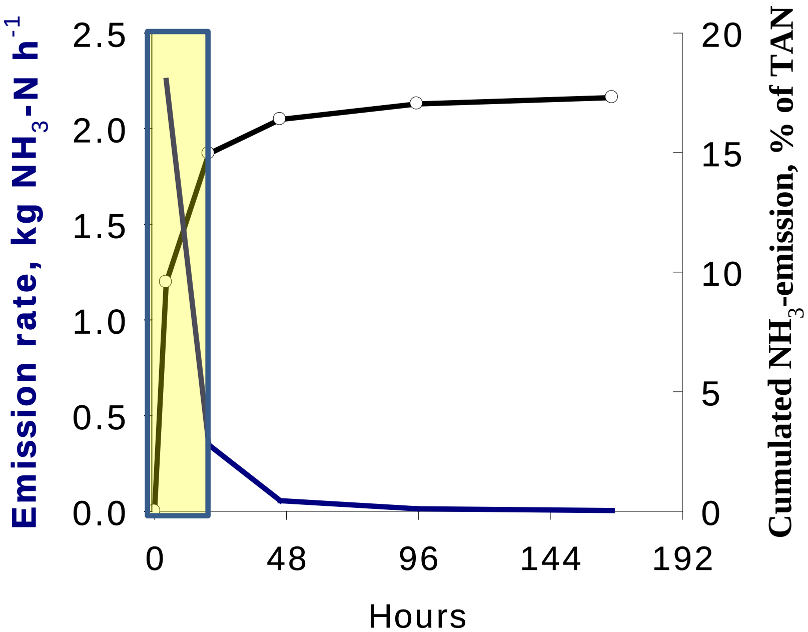
Understanding the system, slurry applied onto soil

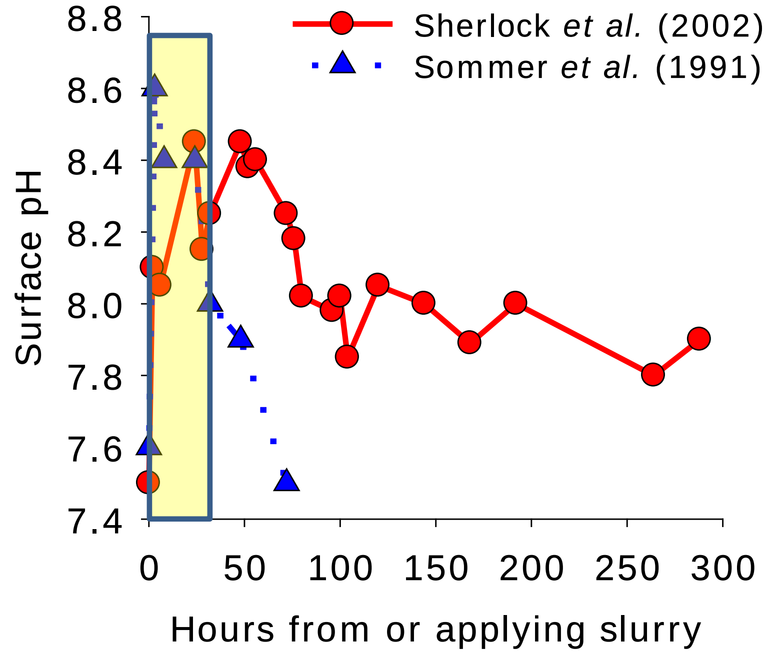


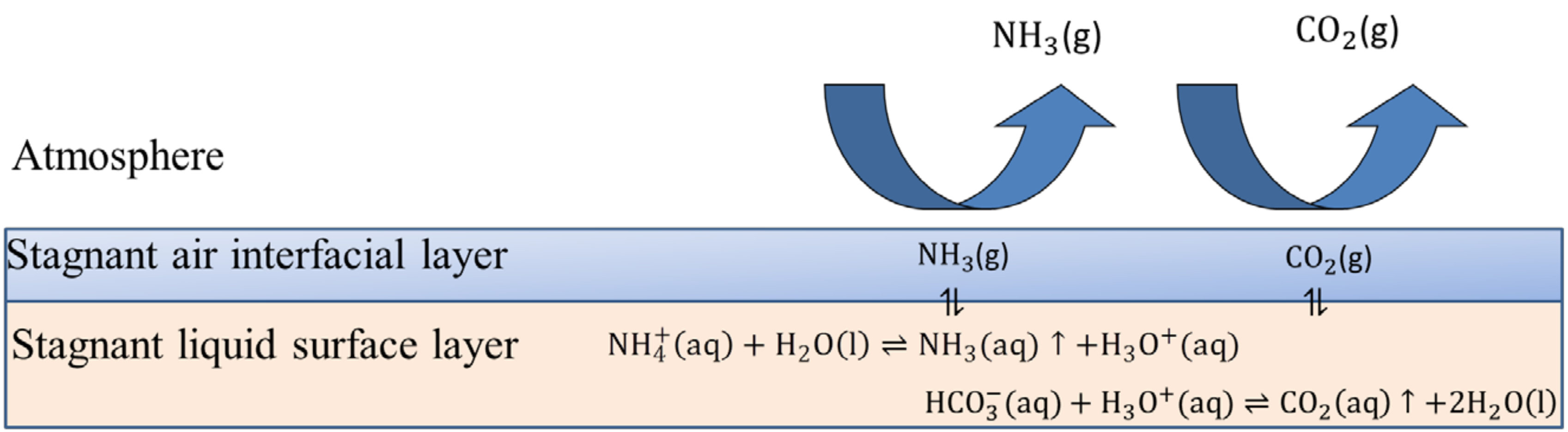
$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) \uparrow + H_3O^+(aq)$$

Slurry applied onto soil

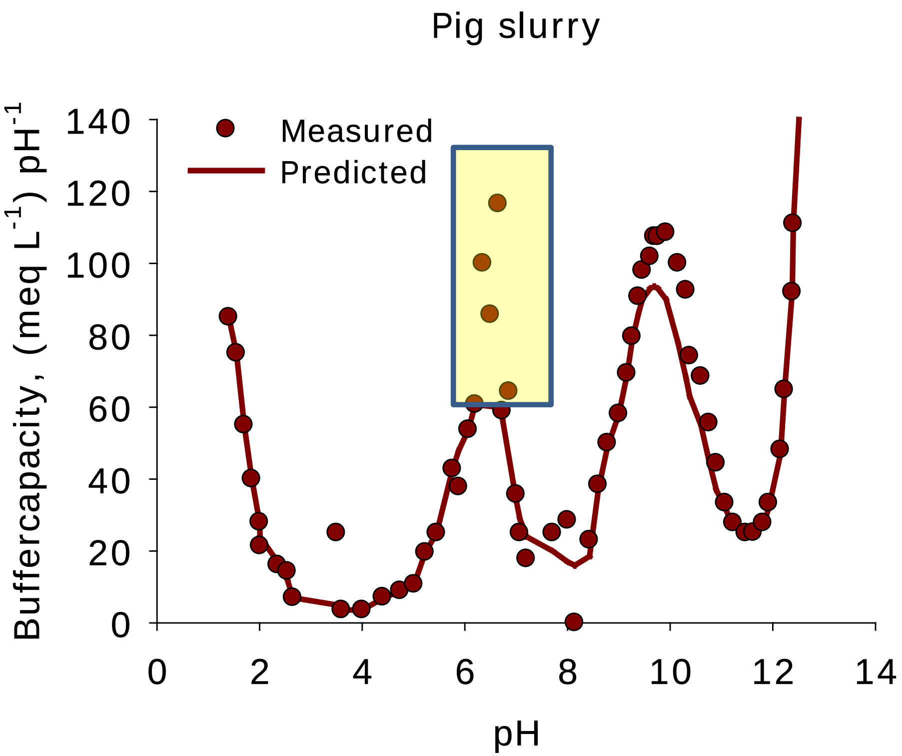
(Sherlock, Sommer, Khan, Wood, Guertal, Freney, Dawson and Cameron, 2002; Sommer, Olesen and Christensen, 1991)







The pH buffer system of animal slurry and anaerobic digested slurry *(Sommer and Husted, 1995)*



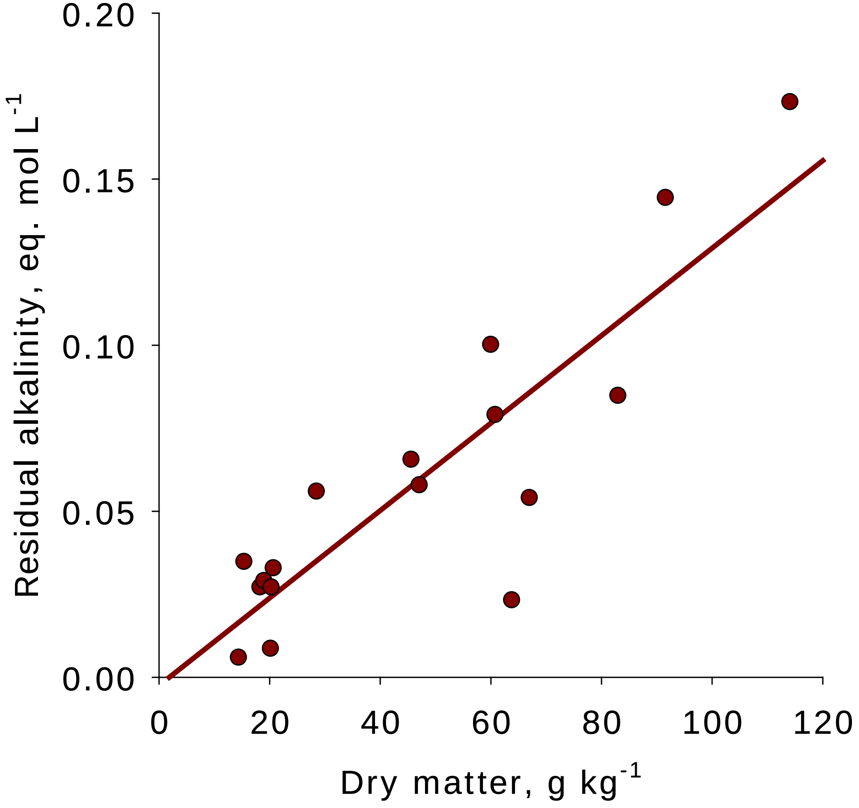
$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

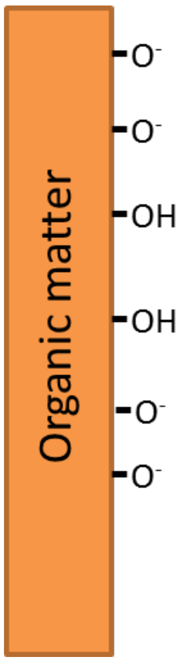
$$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons CO_2(aq) + 2H_2O(l)$$

$$R - COOH(aq) + \ H_2O(l) \leftrightharpoons RCOO^-(aq) + H_3O^+(aq)$$

Electric charge of organic matter - particles

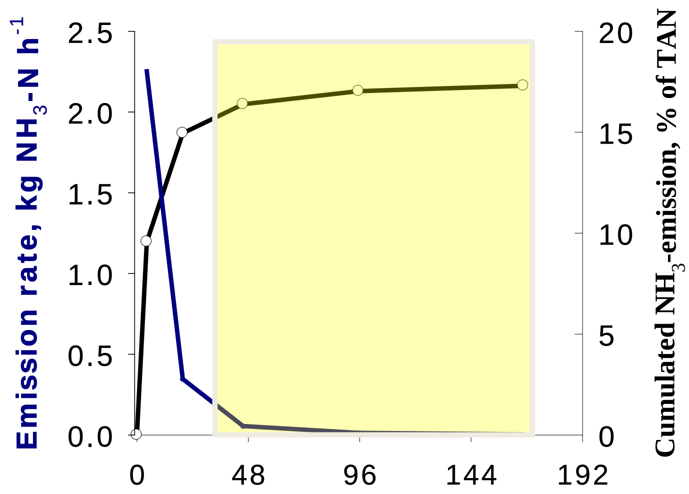
(*Sommer and Husted, 1995*)

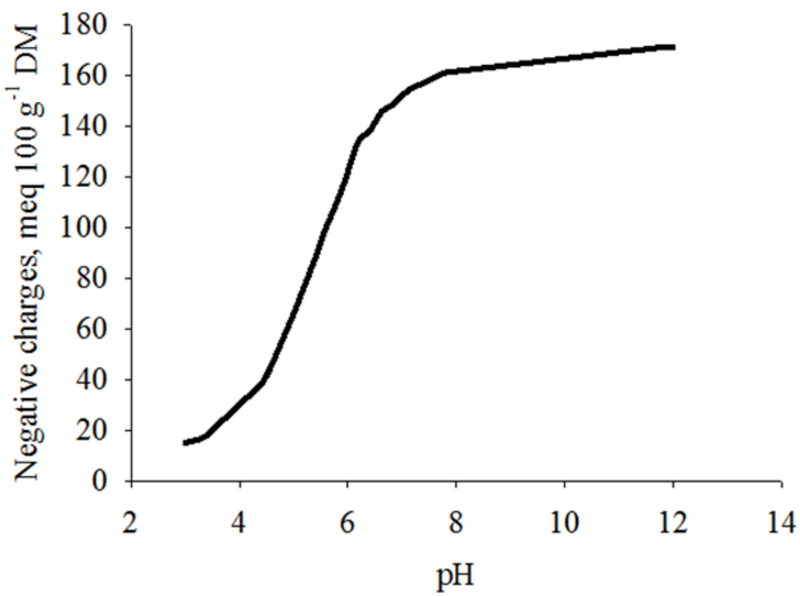


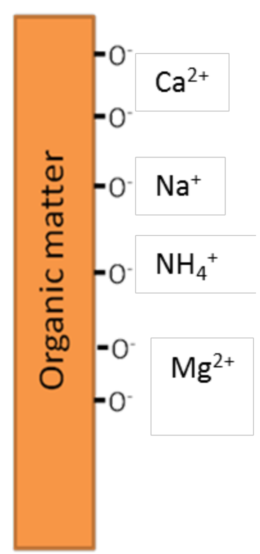


TAL: Total Alkalinity is the amount of equivalents of hydrons (H^+(aq)) that has to be added to the biomass to reduce pH to 4.5.

The negative charged particles may explain the low emissions after 24-48 h – i.e. only 15-20% of the TAN is lost.

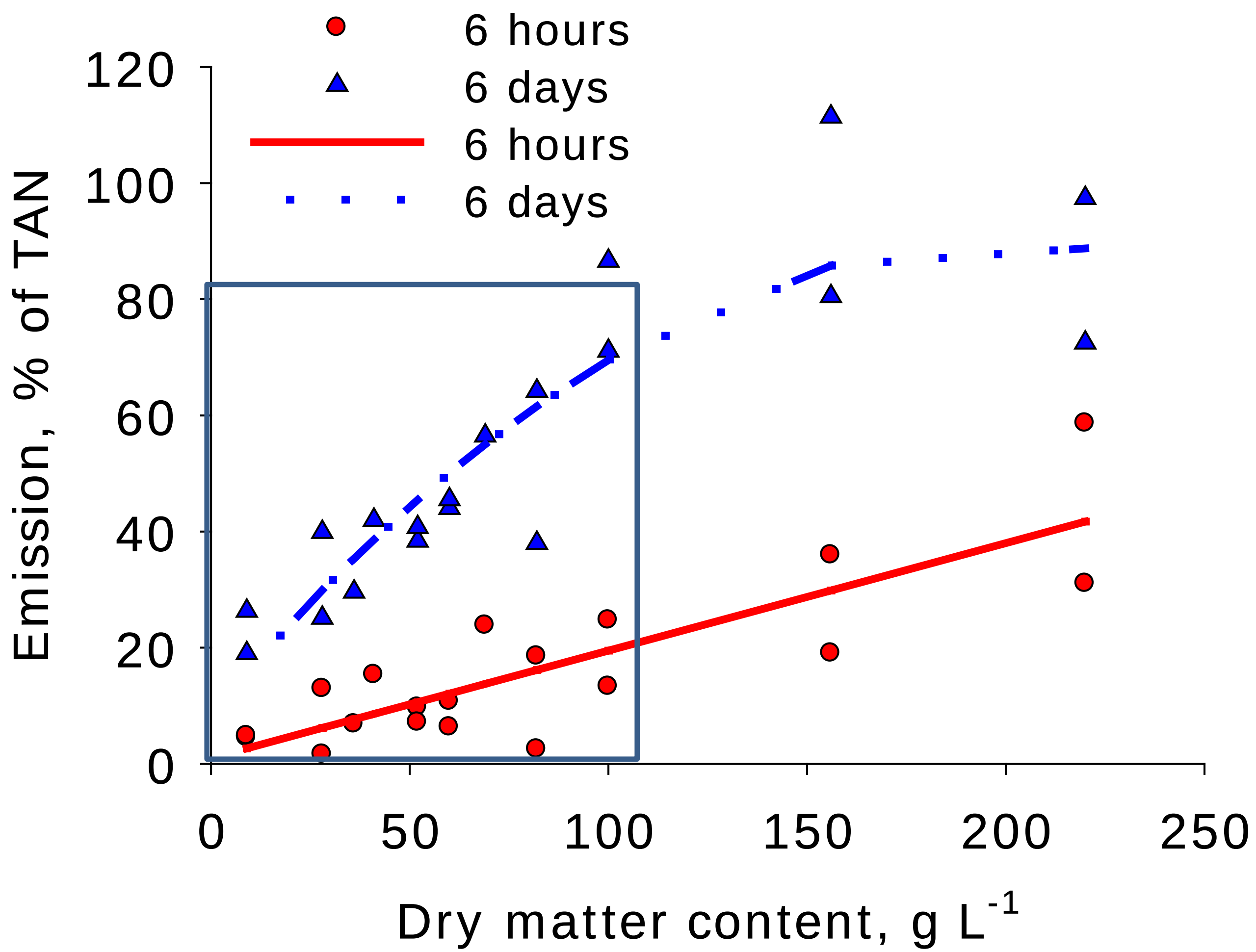






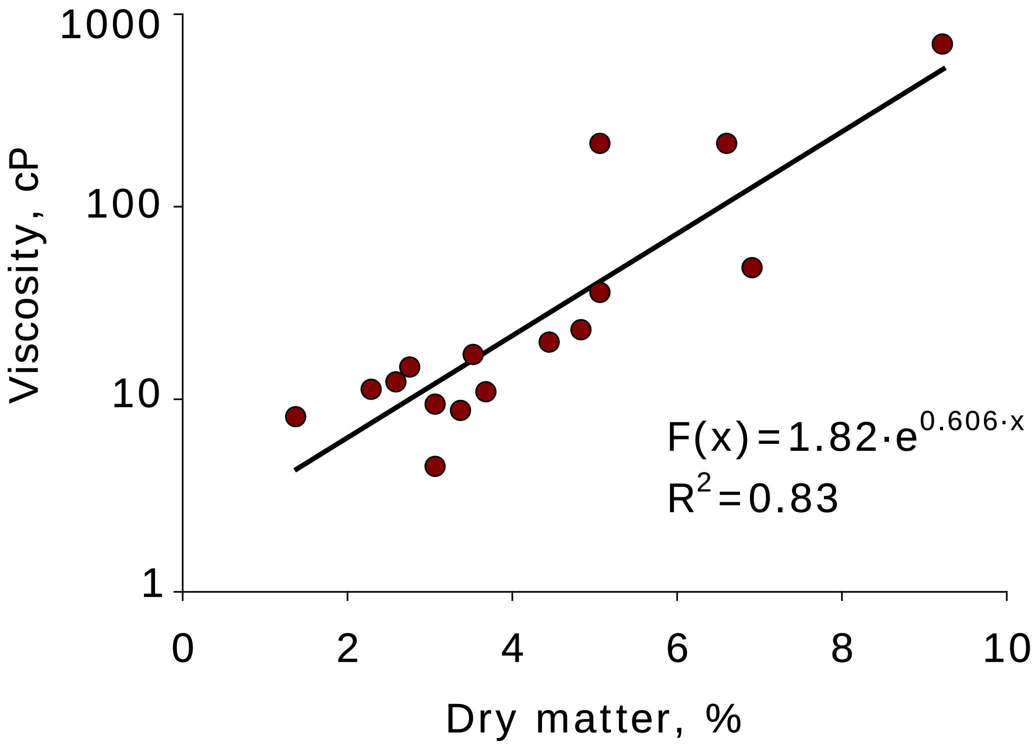
Organic matter (Dry matter) in slurry may also reduce infiltration of slurry liquid containing TAN

(Sommer and Olesen, 1991)



Dry matter (DM) is an indicator of reduced liquid infiltration

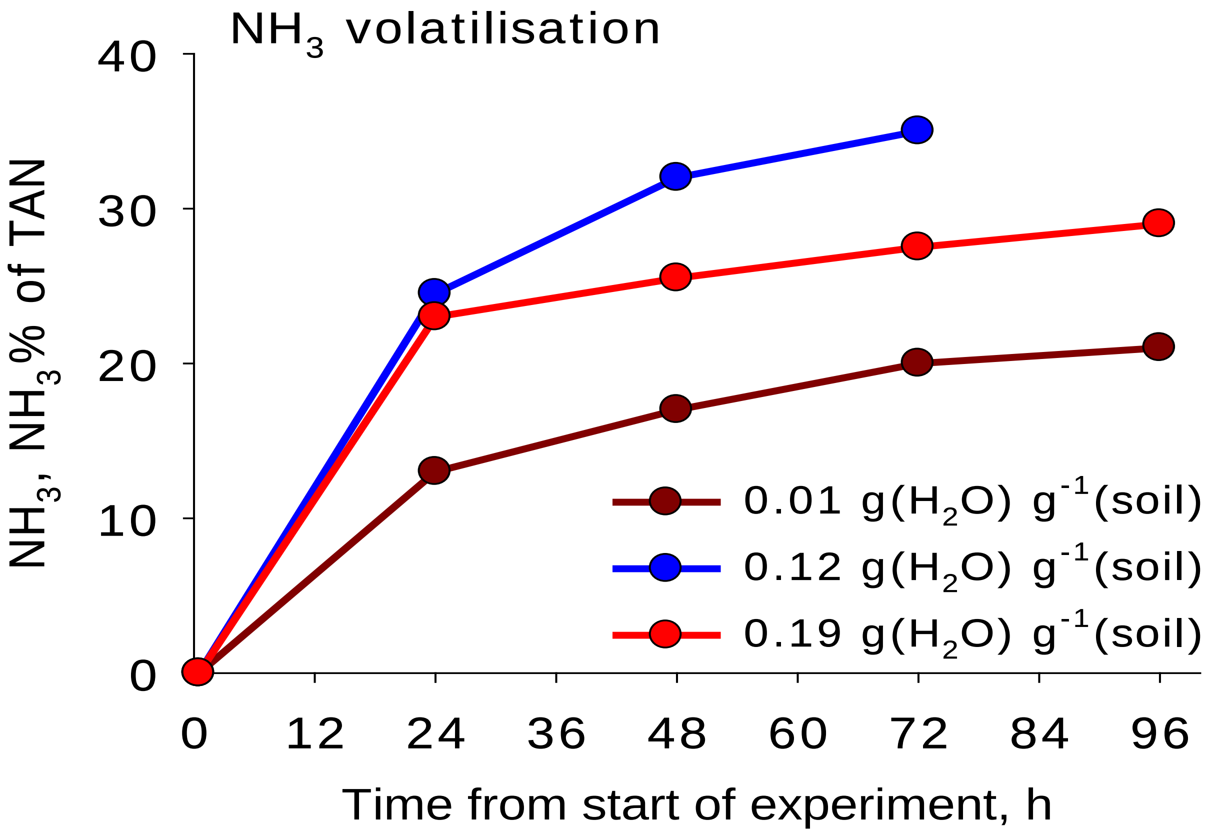
(Thygesen, Triolo and Sommer, 2012)



- High viscosity
- Seal soil surface
- Increase water retention

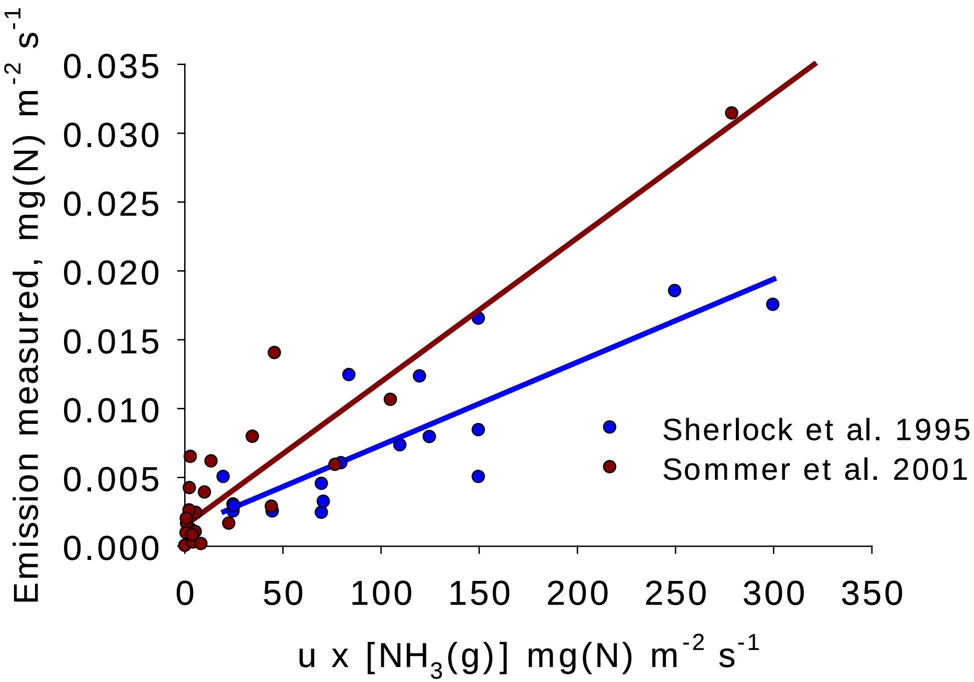
NH_3 volatiliasation vs. infiltration

(Sommer and Jacobsen, 1999)



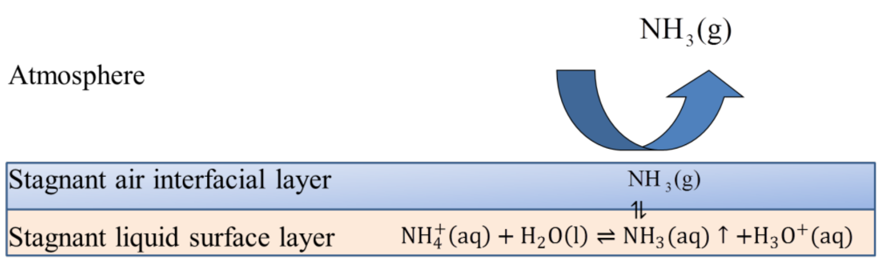
Empirical emission model

(Sherlock, Freney, Bacon and van der Weerden, 1995; Sommer, Søgaard, Møller and Morsing, 2001)



$$F = K \times u \times (\mathrm{NH}_{3,\mathrm{G}} - \mathrm{NH}_{3,\mathrm{A}})$$

- **Wind (*u*)** speed at 1 m above source
- ***K*** dependent on surface characteristic (Here bare soil)
- **Air temperature**
- **TAN** and **pH** in source surface



$$[\mathrm{NH}_{3,\mathrm{G}}] = \frac{1}{H} \cdot \frac{[\mathrm{TAN(aq)}]}{1 + [\mathrm{H_3O^+}]/\mathrm{K_N}}$$

Atmospheric transfer model

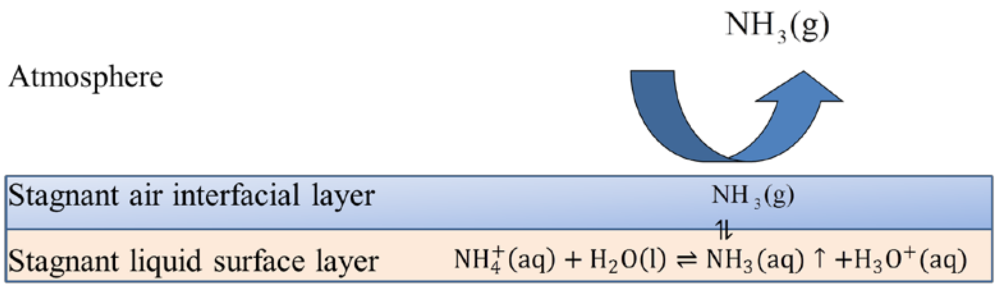
(*Olesen and Sommer, 1993*)

$$F_A = \frac{1}{R_a + R_b + R_c} \cdot ([NH_{3,G}] - [NH_{3,a}])$$

R_a Turbulent air resistance

R_b Laminar air layer resistance

R_c Surface layer resistance



$$R_a(x,t) = \frac{\ln(\frac{l}{z_0})}{\kappa \cdot u_*(t)}$$

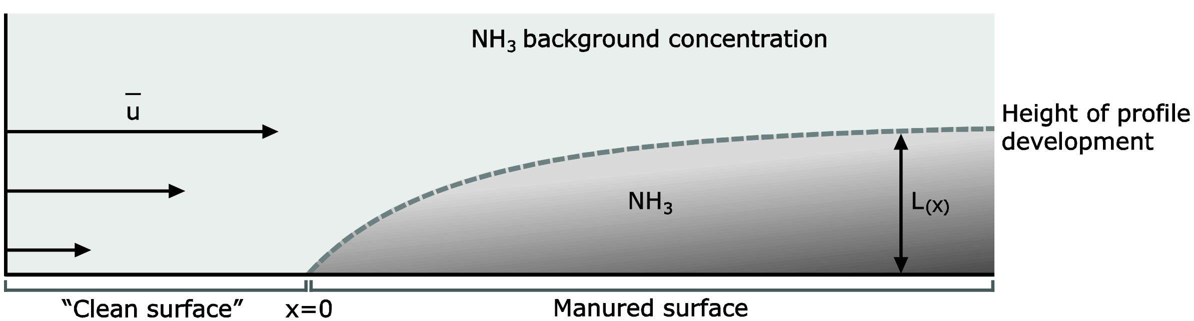
l: height of the internal boundary layer

z_0: roughness length of the surface

U_*: friction velocity

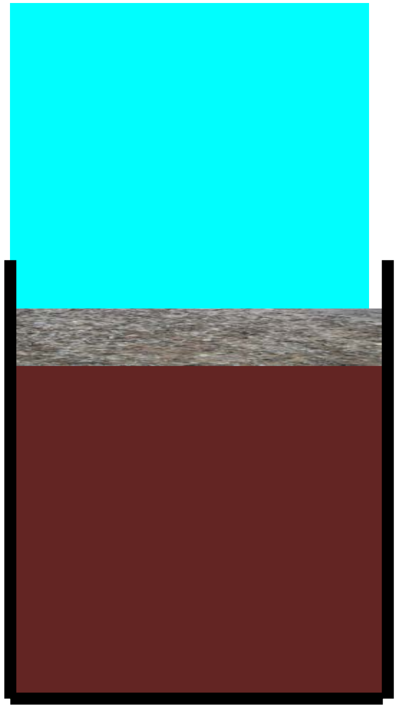
$$R_b = 6.2 \cdot u_*^{-0.67}$$

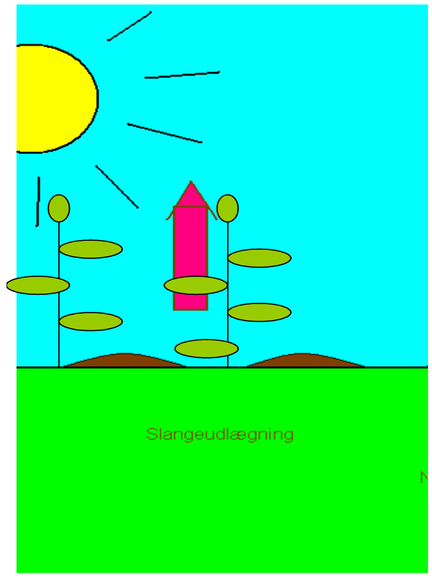
R_c : measured resistance



Atmospheric emission model

(Olesen and Sommer, 1993)





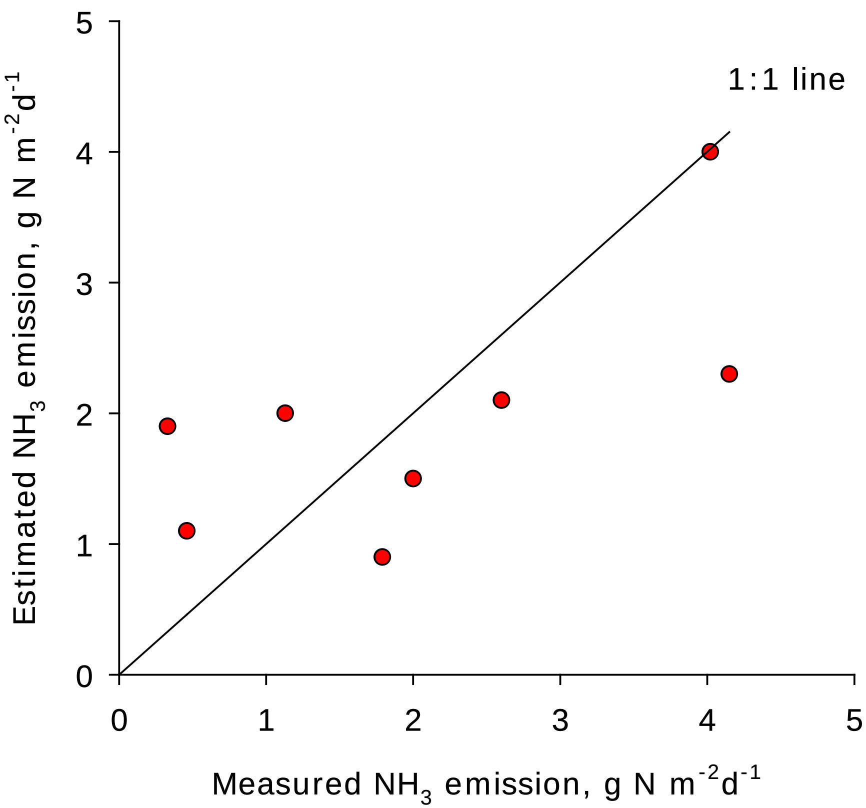
- R_a=18 s m^{-1}; at 8 m s^{-1}
- R_a=71 s m^{-1}; at 2 m s^{-1}
- R_b= 9 s m^{-1}; at 8 m s^{-1}
- R_b=22 s m^{-1}; at 2 m s^{-1}
- R_c= 10 - 230 s m^{-1};

R_c Manure store
Uncovered: R_c= 18 s m^{-1};
Surface crust: R_c=118 s m^{-1}

R_c Fertilizer or manure in field
Bare soil vs. high plants: R_c= 10 - 230 s m^{-1}

Micrometeorological transfer model slurry store

(Sommer, Sibbesen, Nielsen, Schjørring and Olesen, 1996)



Data

Initial bulk TAN and pH

Hourly climate data, air temperature and wind speed

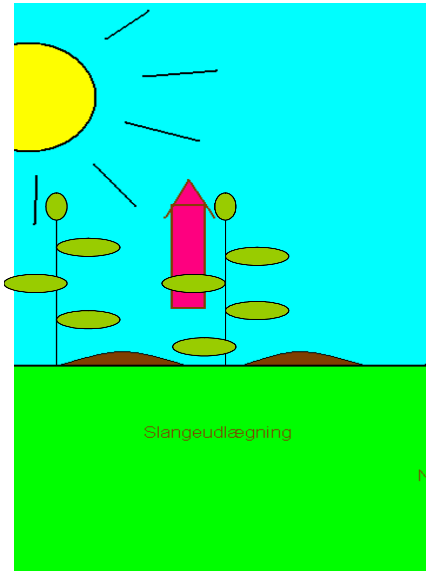
Diffusion/convection transport of TAN in slurry

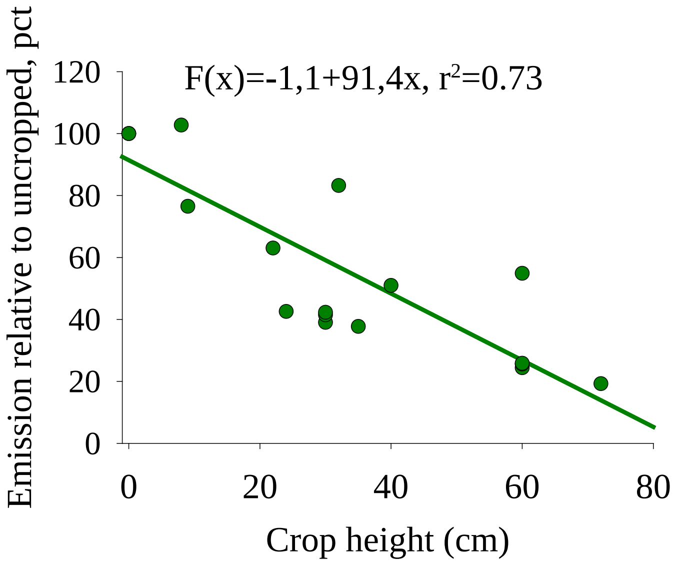
Rc set to =0

Assumed that effect of distance from slurry surface to rim of the tank may improve model performance?

Trail hose application of slurry

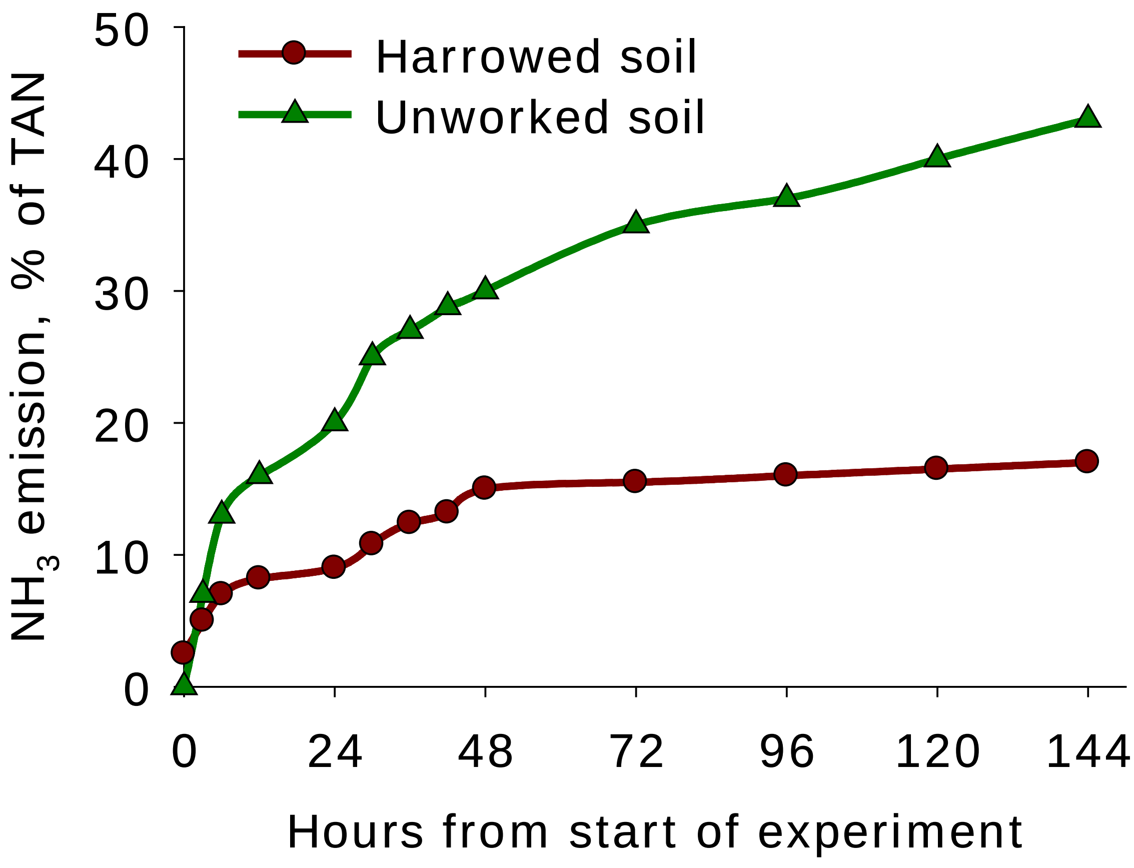
(Thorman, Hansen, Misselbrook and Sommer, 2008)





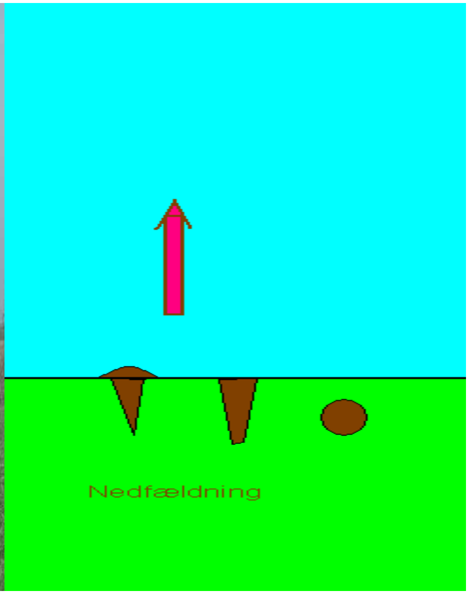
Effect of increasing infiltration – harrowing the soil before slurry application

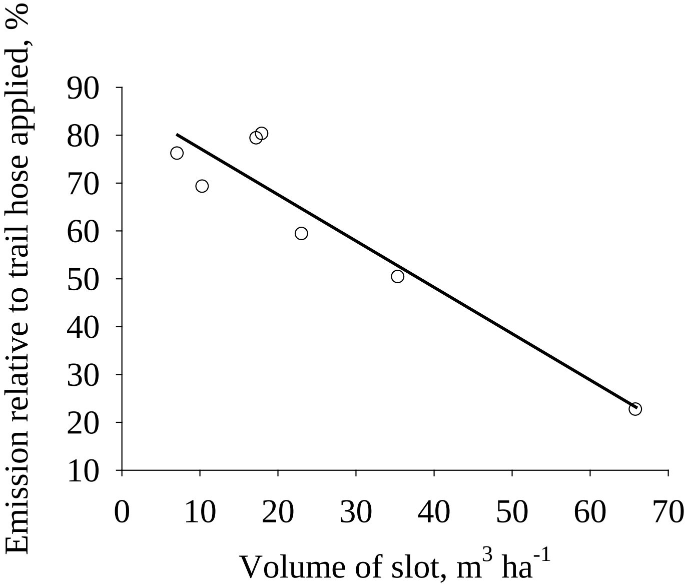
(Sommer and Ersbøll, 1994)



Direct injection of slurry applied in field

(Hansen, Sommer and Madsen, 2003)

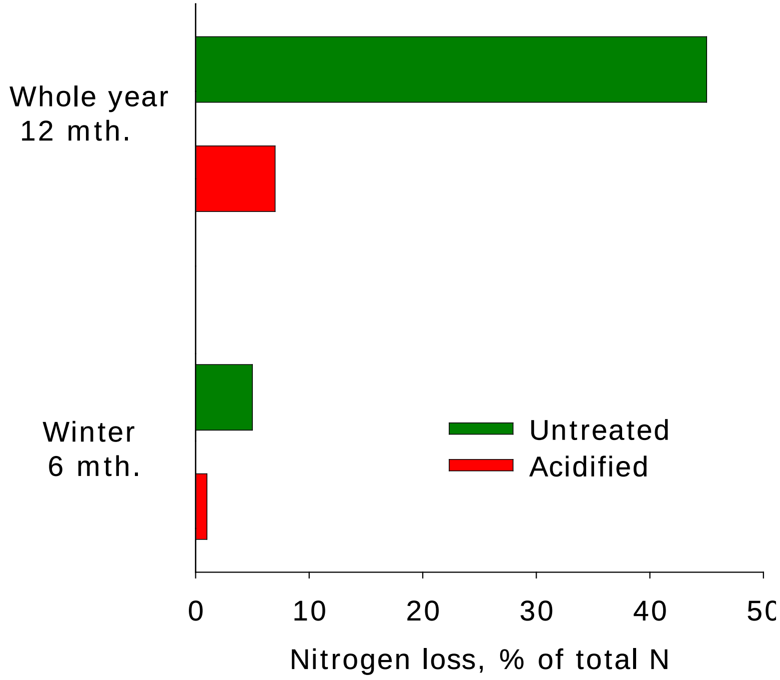




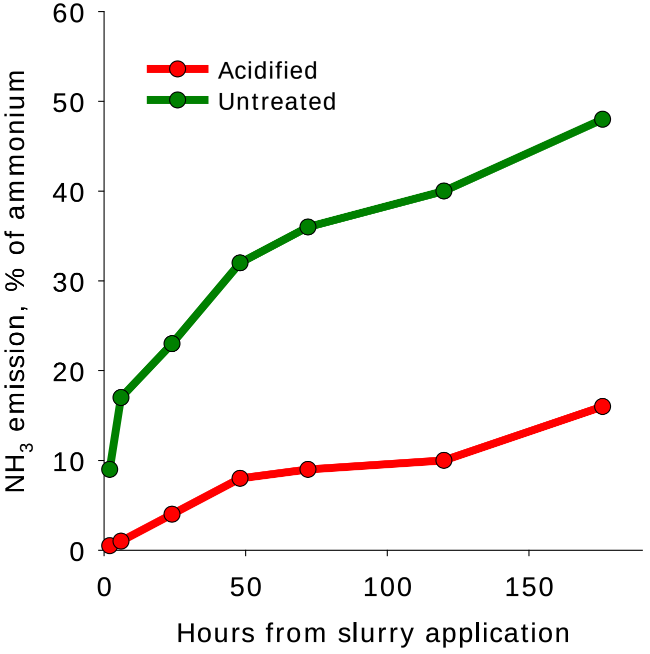
Acidification of slurry

(Kai, Pedersen, Jensen, Hansen and Sommer, 2008)

Slurry storage



Slurry applied in the field



Factors affecting ammonia loss – The ALFAM model

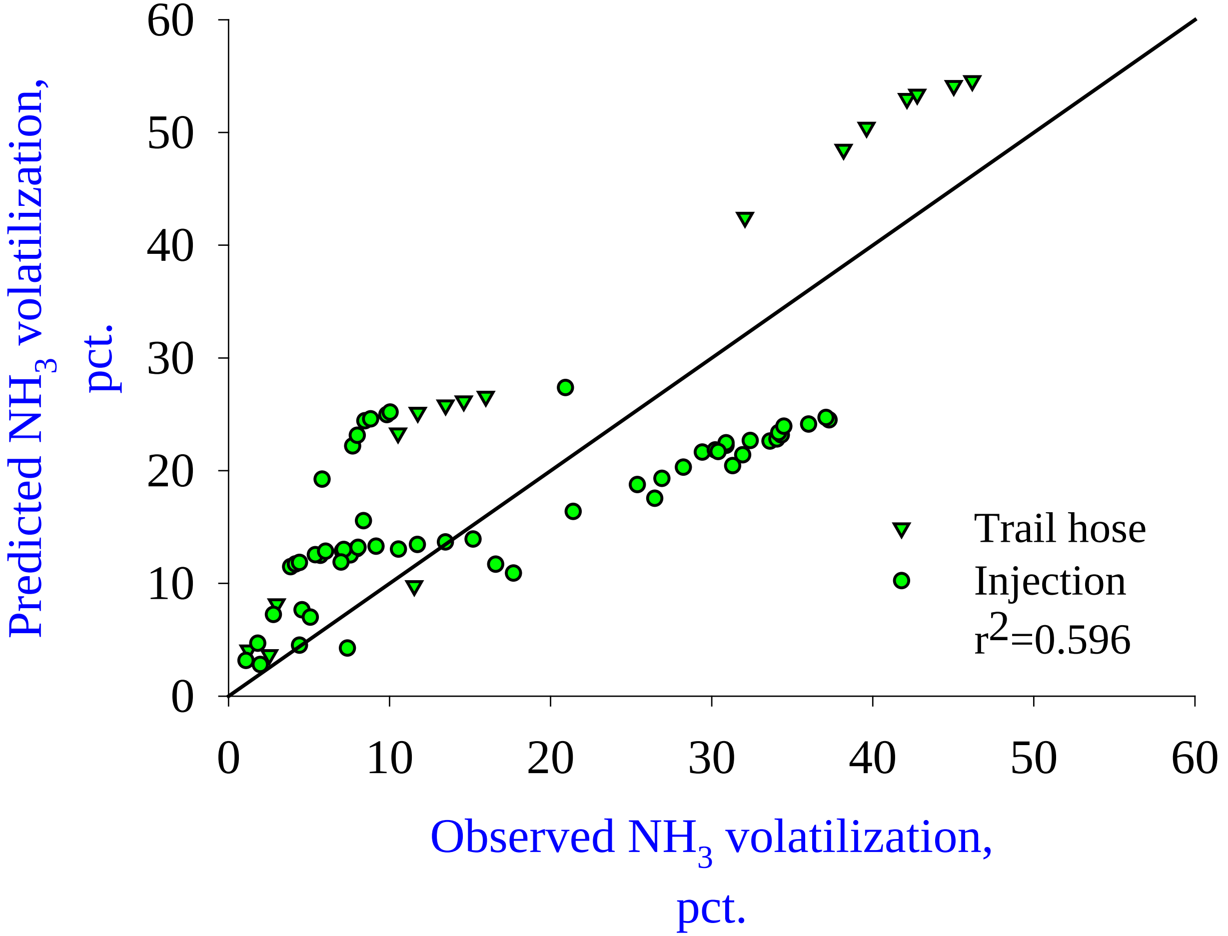
(Søgaard, Sommer, Hutchings, Huijsmans, Bussink and Nicholson, 2002)

Experimental factor	Effect on NH_3 volatilisation
Soil moisture	Wet soil 10% higher than dry soil
Air temperature	+2% per °C
Wind speed	+4% per m/sec
Slurry type	Pig slurry 14% less than cattle slurry
Dry matter content	+11% per % DM
TAN content	Positive
Manure incorp.	No incorp. 11 times higher than shallow cult. and injection

Link: WWW.ALFAM.dk

The ALFAM model – Validation

(Søgaard, Sommer, Hutchings, Huijsmans, Bussink and Nicholson, 2002)



Conclusion

- Efficient techniques to reduce emission are developed and in use
- Models estimating ammonia emission from stored and applied manure should be developed accounting for the environmental condition, manure characteristics, management and treatment
- We need to improve our understanding "source" surface pH

Perspective

- Animal production is increasing and production systems changes without adapting manure management. This lead to increased pollution – which has to be reduced by developing environmentally friendly manure management.