NH3 and dust emissions from broiler houses

Problems and solutions

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- NH3 issues in broiler production
- NH3 emission levels
- NH3 mitigation options
- dust (PM10/PM2.5) problems in broiler production
- PM concentration and emission levels
- PM mitigation options
- outlook
Europe population and livestock distribution
Ammonia cycle

Transport and reaction

\[ \begin{align*}
\text{NH}_4\text{HSO}_4 \\
(\text{NH}_4)_2\text{SO}_4 \\
\text{NH}_4\text{NO}_3
\end{align*} \]

Deposition

\[ \text{NH}_3 \quad \text{NH}_4^+ \]

Emission

Effects - Acidification
- Eutrophication
- Loss of biodiversity
Environmental problems related to NH3 emissions

Majority of NH3-emissions in Europe (>90%) from livestock production, sources: barns, storage and application of manure

- NH3-emissions => leads N-deposition in natural areas => eutrophication/acidification => loss of biodiversity
- NH3 in ambient air: major precursor in formation of secondary dust particles (PM2.5) => ambient PM concentration are associated with health problems
- High NH3 concentrations in barns deteriorate working and animal conditions (> 20 ppm)
Ammonia deposition in the Netherlands

- mole-eq./ha
- critical load >1000
- high excess levels in east/centre/south
- areas with > 2000 pigs/km²
Effects of N deposition: loss of biodiversity

NL: since 1990’s development of mitigation options in animal production:

- Housing systems
- Manure application techniques
Ammonia formation in broiler litter

- Around 65% of total N-intake is excreted: not-digested (17%), not-utilized (48%, uric acid)
- Microbial conversion of uric acid and undigested proteins into NH₃:

  \[
  \text{uricase} \\
  C_5O_3(NH)_4 + \frac{1}{2}O_2 + 8H_2O \rightarrow 2CO(NH_2)_2 + 5H_2O + CO_2 + COHCOOH \\
  \rightarrow 4NH_4^+ + 4OH + 3CO_2 + COHCOOH \text{ (glyoxyl acid)}
  \]
Ammonia formation in broiler litter

- Important conversion parameters: N efficiency, DM litter, pH, oxygen availability (litter compaction)

- Emission processes: multi-factor process, not all elements fully understood
NH3 emission patterns in broiler production

Traditioneel

Netherlands standard conditions: 18 – 24 birds/m2, litter based on wood chips/sawdust, litter removal every round

DM effect of litter on relative NH3 emission
NH3 emission measurements

Recent emission measurement campaigns show strong differences between management systems:

Moore et al. 2011, US, 4 barn locations, 1 year average:
- 37.5 g NH3/bird marketed (50 d), and 9.0 g NH3/bird between flocks

Mosquera et al. 2010, NL, 4 barn locations, 1 year average:
- 10.3 g NH3/bird marketed (40 d), litter removal between flocks
Variability ammonia emissions

Variation coefficient between farm locations: 35%

Ventilation rate (m³/h per animal)  Ammonia emission (kg/year per animal)

Mosquera et al. 2010, NL, 4 barn locations
NH3 emission factors for broiler barns

Emission factors used in permit procedures, expressed in g per year and animal place:

Germany: 50 g NH3
Netherlands: 80 g NH3
NL- recent measurements: 72 g NH3
NH3 mitigation options for broilers

- Feed composition: less not-utilized N, less ammonia formation

- Litter conditioning/treatments: decreasing ammonia formation

- Air purification of ventilation air: removing ammonia by air scrubbing

To be accepted as BAT in NL: < 45 g NH3/year per bird
Effects of feed composition

Reducing N-excretion:
- Decreasing CP content and free amino acids: NH3-reduction potential 25%
- Intensified phase feeding: increasing N efficiency, NH3-reduction potential 20%

- Working principles demonstrated in experimental research
- Will be implemented as recognized mitigation options in NL coming years, after validation on commercial farms
Litter conditioning measures

- Three different air recirculation systems have been developed that increase dry matter in litter by improved air distribution, and significantly decrease NH3 emission.

- Air recirculation systems have been evaluated on commercial farms using a standardized measurement protocol for emission factors.
Air recirculation by auxiliary vertical fans

Improves litter conditions and microclimate for birds

1 fan every 150 m²
Maximum capacity 1.8 m³/h per bird
(picture Fancom, Imago system)
Air recirculation by vertical heater fans

Cross sectional view

Top view barn

1 fan + heater: every 450 m²
Central heating system
(picture Wesselman heaters)
Air recirculation in combination with heat exchanger for inlet air

Air supply through heat exchange unit and distribution pipes

(pictures Plettenburg air handling)
**Emission factors: NH3 mitigation systems for broiler production**

<table>
<thead>
<tr>
<th>NH3 mitigation system</th>
<th>NH3 emission factor (g NH3/year per animal place)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference level: conventional broiler barn</td>
<td>80</td>
</tr>
<tr>
<td>Air recirculation: auxiliary vertical fan</td>
<td>37</td>
</tr>
<tr>
<td>Air recirculation: vertical heater fans</td>
<td>35</td>
</tr>
<tr>
<td>Air distribution system and heat exchanger</td>
<td>21</td>
</tr>
<tr>
<td>Chemical air scrubber (90% NH3-reduction)</td>
<td>8</td>
</tr>
<tr>
<td>Biological air scrubber (70% NH3-reduction)</td>
<td>24</td>
</tr>
</tbody>
</table>
Process scheme of conventional scrubber/biotrickling unit

- Air inlet
- Air outlet
- Fresh water supply
- Recirculation
- Packing 3 m³
- Buffer tank 35 m³
- Water discharge
- 20,000 m³/h
Air scrubbers in livestock industry

- Both chemical and biological scrubbers are applied since ~1995
- Currently about 10% of pig production is using scrubbers
- Very limited use in poultry industry until recently because of clogging problems
- Biological and chemical scrubbers are now introduced again in poultry industry because of their PM10 removal capacity
Costs of mitigation systems in broiler production

<table>
<thead>
<tr>
<th>Mitigation system</th>
<th>Investment costs</th>
<th>Yearly depreciation</th>
<th>Yearly extra</th>
<th>Total extra costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical fans</td>
<td>0.68</td>
<td>0.10</td>
<td>0.00</td>
<td>0.10</td>
</tr>
<tr>
<td>Vertical heater fan</td>
<td>0.42</td>
<td>0.06</td>
<td>-0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Heat exchanger + air distribution</td>
<td>1.11</td>
<td>0.13</td>
<td>-0.10</td>
<td>0.02</td>
</tr>
<tr>
<td>Chemical air scrubber</td>
<td>3.30</td>
<td>0.44</td>
<td>0.43</td>
<td>0.87</td>
</tr>
</tbody>
</table>
Background fine dust challenge

Effects fine dust (PM10 and PM2.5) on human health

EU set limits on fine dust in outside air
PM10: 40 $\mu$g/m$^3$ yearly limit PM10
PM10: 50 $\mu$g/m$^3$ daily limit with max 35 crossings
PM2.5: 25 $\mu$g/m$^3$ yearly (2015)

NL: derogation request to reach threshold values PM10 by 2012

National mitigation programme to meet targets 2012
NL: PM10 concentration levels

Red: areas where EU threshold values are exceeded in 2010
Fine dust: main sources

Bronnen van fijn stof

(source Ministry of Environment NL)
Litter-based poultry barns main agricultural source
Dust in animal production: mainly originating from manure/litter and feathers
Mass distribution of dust over different particle size classes: fattening pigs and broilers

(Aarnink et al., 1999)
Contribution PM10 from agriculture

- 20% primary PM10 from poultry and pig houses, especially bedding systems
- Approx. 100-150 poultry farms do not comply with PM10 standards
- Agricultural sources part of the national mitigation program to meet PM10 targets for 2012
Research and development programme for dust reduction options for poultry farms

Objectives:

- Practical technology, tested and farm ready
- As soon as possible available (from 2009 on)
- Close cooperation between Livestock Research of Wageningen UR and supplying industry
- Financed by Ministries of Agriculture and Environment
Inside air quality

Feed
- Water content
- Fat content
- Coating pellets
- Form: meal, crumb, pellets
- Ingredients

Animal
- Species
- Genotype
- Age
- Number

Faeces + urine
- Pen fouling

Bedding
- Kind
- Water content
- Amount
- Refreshment

Dust on surfaces

Force
- Processing / transport feed / bedding
- Chewing
- Trampling
- Scouring
- Drying

Outside air quality

Airborne dust in animal house

Force
- Animal activity
- Human activity
- Supplying feed / bedding material
- Air flow

Dust emission to outside air

Force
- Ventilation

Inside air quality

Force
- Sedimentation
Selection of main dust reduction options for poultry

- Light schedules (affecting animal activity)
- Litter/bedding (materials, management)
- Oil film application
- Ionization techniques
- Air scrubbers (simple and multi-stage)
- Drying tunnels using ventilation air
- Water film application
- Electrostatic devices and dry dust filters
- New concepts proposed by industry
Development of methods to measure high dust loads from animal housings

Inlets, cyclones PM10 en PM2.5, filter
Exact air flow: 1.0 m$^3$/h
NEN-EN 12341, 1998; NEN-EN 14907, 2005
Sampling set up in broiler house
Broiler rooms

- Rooms 5-8: oil spraying
- Rooms 2, 3: ionization
- Rooms 1, 4 control rooms
- Room: 8.3 x 16.0 m
- Standard broiler housing and equipment
- 20 broilers per m²
- Total 2675 broilers per room
- Mechanical ventilation: cap. 21 000 m³/h
Litter type broilers

- Working principle: less particulates in litter. Potential reduction 10-20%?

Investigated materials:
- sawdust
- Cut wheat straw
- Cut rape seed straw
- Maize silage

- Conclusion: no effect on PM10 emission
- Side effect: maize silage < NH3 emission
Light schedules

- Working principle: less animal activity, potential reduction 10-30%?

- Different light schedules investigated:
  - Comply with welfare regulations
  - No or minimal effect in broilers
Oil film application in broilers:
Principle of oil film application

- Sticking dust particles to litter by tiny oil film
- Less generation of particles into air by animal movement
- Daily administration during small intervals (20 seconds) of oil mist (rape seed oil)
Oil spraying

- Rapeseed oil
- 2 oil lines, 2 air lines
- 4 nozzles/tube
- Spraying area: one line: 8.3x8.0 m
PM emission pattern during the growing cycle

\[ Y = -0.19 + 0.12 \times (1.14)^X \]

\[ R^2 = 100\% \]

PM10 emission: 88% during last 2 weeks
PM2.5 emission: 95% during last 2 weeks
Results: effect oil dose on PM reduction, rounds 1 - 3

\[ y = 1.71x + 44.4 \]
\[ R^2 = 0.77 \]

\[ y = -0.24x + 85.3 \]
\[ R^2 = 0.02 \]
Effect spraying interval on PM reduction

Daily spraying gave 23% more PM10 reduction than spraying every other day (P=0.05)

No difference was found for PM2.5
No significant effects on animal health

Improved air quality inside
Effect oil dose on personal exposure to PM10

\[ y = 0.65x + 64.1 \]

\[ R^2 = 0.24 \]
Cleaning item in oil film application broilers

Cleaning: more time needed; this can be reduced by:

Reduced oil application: starting at 21 d, less oil per m² per day

Application at floor level: mobile system, autonomous oil robot with spraying beam is in development
Oil film application: introduction in practice?

- Tested on two farm locations, according measurement protocol PM10
- Results confirmed earlier observations on experimental farms

- Attention required for costs (extra cleaning time)
- Application in layer houses so far not possible
Application of ionization techniques in broiler houses

• Working principle: loading particles with electrons by corona’s, attachment of loaded particles to surfaces

• Electrostatic Particle Ionization (EPI) system
Ionization set up at experimental poultry farm

- 2 lines with discharge electrodes
- 2.5 m above litter
- -30 kV DC
- 0.4 – 0.7 mA
Experimental set-up ionization in broilers

Two growing cycles

2 ionization rooms; 2 control rooms
Additional measurements ionization in broilers

Ion concentration

Ozone concentration

Ultra fine particle concentration (range 5 – 1100 nm)
Results ionization

Mean ion concentration: 1,800 ions/cm$^3$, ranging from 220 – 6,400 ions/cm$^3$

Ozon concentration: < 0.01 ppm

Ultra-fine particle count (range 5 – 1100 nm): 45% lower in ionization rooms
Results ionization

System worked correctly during whole experiment

Amperage decreased gradually from 0.7 – 0.4 mA during the growing cycle

Cleaning of plates gave slight increase of current

PM10 reduction: 36% (P<0.001)

PM2.5 reduction: 10% (P<0.05)
Ionization: introduction in practice

- Tested on two farm locations, according measurement protocol PM10: control-case approach on both farms.

- Results are better than earlier observations on experimental farms: average PM10 removal rate 50%
Look for the treatment
Outlook

- Testing phase of abatements techniques for broilers was successful: a strong demonstration effort is required for practical implementation.
- For layer houses only end-of-pipe techniques are currently available: more research needed here.
- In general this program showed that quick solutions can be achieved if industry and research work closely together from an early phase.
Thank you for your attention