Reconciling livestock management to the environment

Applying Best Available Technique (BAT):
from the lab to the farm

European workshop
Rennes, France – 19 & 20 March 2013

Annexe 2

PowerPoint illustrations used during presentations made in the workshop

24 March 2013
Irstea

National Research Institute of Science and Technology for Environment and Agriculture

Pour mieux affirmer ses missions, le Cemagref devient Irstea

9 centres + 2 locations hors centres (Strasbourg et Martinique)
20 research units
5 research unité with research institutes and engineers schools) (Cirad, Inra, IRD, Engees, AgroParisTech, SupAgro)
1600 employees with
950 engineers and researchers
200 PhD students and 40 post-doctoral students
Budget 2011 : 115 M€ including 31% contracts resources
Irstea Rennes Research Centre

Buildings B1, B2, B3,...

1976

Main building

2 extensions

1988 : Unit TERE

1998 : Unit GERE

Irstea Rennes Research Centre

Surface utile
B1 : 1060 m²
B2 : 1630 m²
B3 : 1233 m²
B4 : 36 m²
Total : 3959 m²
Irstea Rennes Research Centre
The people!

- 60 permanent staff
- 13 PhD students
- 8 post-doc and short term contracts
- ≈ 25 trainees
- ≈ 7 M€ (2012) budget among:
  - 4.2 M€ personnel cost
  - 2.8 M€ running and investment costs
  - et personnel "temporary"

- 2 Research Units
- 2 Research Topics
- Associate Member European University of Brittany
- Associate member of doctoral schools (SDLM, VAS)
**Irstea Rennes Research Centre**

**Director**
José MARTINEZ

**Services généraux**

**Finances and accountant**
Monique THEBAULT Patricia MANACH

**Human resources**
Brigitte ORAIN Marie-Noëlle MAUDET

**Library - Communication**
Regina LOUBAT Brigitte MARCHIX

**Logistics works**
Philippe ESNAULT Eric LE SAOS

**Research Units Assistants**

**GERE Research Unit**
- Environmental management and biological treatment of wastes
  - Director: Fabrice BELINE

**TERE Research Unit**
- Food technology equipment
  - Director: François MAHETTE

**Information systems computers**
RÉ : Fabrice EGIDO DIR + UR GERE
ASI : Amina OMAR DIR + UR TERE

**Types and Amounts**

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<th>Type</th>
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<tr>
<td><strong>Research</strong></td>
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<tr>
<td>• National Research Agency (6)</td>
<td>1 392 214 €</td>
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<tr>
<td>• Europe (2)</td>
<td>346 177 €</td>
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<tr>
<td>• ADEME Agency (6)</td>
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<td>• Brittany Region(9 + 4)</td>
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<td>• Others Regions (2)</td>
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<td>• Private partners(6)</td>
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<td>Ministries (3)</td>
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<td>Others (INRA, collectivities, …)</td>
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<td><strong>Equipment</strong></td>
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<td>• Rennes City</td>
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<tr>
<td>• Brittany Region</td>
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<td><strong>Sous-total (3)</strong></td>
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<td><strong>Total (1) + (2) + (3)</strong></td>
<td>4 061 722 €</td>
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() contracts number

BATFARM – 19 March 2013 – José MARTINEZ
Budget 2012 Rennes Centre

Income

Expenses

Temporary staff
Incentive funding
Contract resources

Temporary staff
Postponement
Inter-centres transfers

Running & investment costs
Pharamaceutical projects
Social activities and training

Inter-centres transfers

3 007 297 €

Excellence International Chair
University European of Brittany

2010-2012 – Suzelle Barrington
Professor-Research Mc Gill
University (Montréal – Canada)

Increase the visibility of a cluster process engineering and applied environmental waste

« UEB » initial budget : 300 k€ (240 k€ endowment)
Final budget chair : 900 k€
3 PhD students, 2 post-doc
Specific equipment (olfactometer)
Projects
Reconciling livestock management with the environment

Applying Best Available Techniques (BAT) ….. from the lab to the farm

European workshop – Irstea, Rennes, France
19, 20 March 2013

Workshop Organiser: L LOYON

Welcome by Dr José Martinez,
Regional Director of Irstea at Rennes

Administration matters

- Early departures
- Lunches at the Mercure Hotel
- Evening meal Tuesday 19 march
  - 19h Visit of the Museum of Brittany (appointment at 18h50): dinner to follow at 20h45
- Attendance sheet

Introduction to workshop
Introduction to workshop

Workshop organised and funded under the European Interreg Project BATFARM (www.batfarm.eu) which is lead by the NEIKER (Spain)

Context of the workshop

• Livestock is responsible
  – for NH₃ emissions (94% of European emissions in 2009)
  – for GHG emission (18% of world emissions)
  – for Nitrate pollution of water resources
  – For dust emissions: PM₁₀⁻₂,⁵...
• Urgent need to reduce these emissions
  – In general , to comply with
    • different international protocols (Göteborg, Kyoto,....)
  – Under IPPC/IED to obtain a permit for operating intensive livestock units (pig and poultry), with an on-going revision of the BREF guidelines
• Many questions relating to BAT selection and application
• However, at present there is no standard tool or document on BAT selection and application (whether IPPC/IED or not)
Objectives and expected outcomes of this workshop

- To promote the exchange of scientific and technical information on BAT selection and application
- Specifically in response to certain key questions, including:
  - Which technique for which environmental impact (air/soil/water)?
  - Level of knowledge of the suitability of a given technique for different impacts?
  - Limits of applicability of any given BAT
  - Level of precision (with respect to the reduction allocated to a given technique) that we can reliably expect (e.g.: 50% reduction ±??%)?
  - How to control the efficiency of a BAT technique applied at the farm level? (e.g.: Vera protocol or new EU ETV)?
  - Method of emission measurement to evaluate various techniques?
  - What is the best way to show the reduction achieved by using a BAT (level of reduction, cost, technical applicability, ...)?
- To explore the opportunity to submit a paper based on this workshop
- Possible European follow-on project: publication of a reference book

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Workshop agenda

**Tuesday 19th March 2013**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>9h-10h</td>
<td>Welcome</td>
<td>J. Martinez, Director of Irstea Rennes Centre</td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
<td>L. Loyon, C. Burton, Irstea &amp; Consultant</td>
</tr>
<tr>
<td></td>
<td>BATFarm Project</td>
<td>P. Merino, Neiker, Spain</td>
</tr>
<tr>
<td></td>
<td>IMPEL Presentation 1</td>
<td>M. Florean, Ministry of Environment and Climate Change, Romania</td>
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<tr>
<td></td>
<td>Coffee Break</td>
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<tr>
<td>10h30-12h45</td>
<td>Session 1: Nutrition</td>
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<tr>
<td></td>
<td>Cattle</td>
<td>M. Doreau, INRA, Theix, France</td>
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<tr>
<td></td>
<td>Poultry</td>
<td>T. Veldkamp, Wageningen UR, NL</td>
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<tr>
<td></td>
<td>Pig</td>
<td>J.Y. Dourmad, INRA, Saint Gilles, France</td>
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<tr>
<td></td>
<td>IMPEL Presentation 2</td>
<td>A. Holdsworth, Environmental Agency, UK</td>
</tr>
<tr>
<td>14h-17h45</td>
<td>Discussion</td>
<td></td>
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<tr>
<td></td>
<td>Lunch Break</td>
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<tr>
<td>18h</td>
<td>Visit of the Museum of Brittany and 20h45 Dinner (restricted)</td>
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### Workshop agenda (continued)

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<th>Time</th>
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<tr>
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<td>S. Sommer University of Southern Denmark, Denmark</td>
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<td>A. Bonmati Giro, Spain</td>
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<tr>
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<td>J. Webb AEA, UK</td>
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<td>T. Sameiro de Sousa Ministry of Agriculture and Environment, Portugal</td>
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<td>E. Grimm KTBL, Germany</td>
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<td>M. Aguilar INTIA, Spain</td>
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### Opening Presentations

- The BATFarm Project | P. Merino Neiker, Spain
- IMPELPresentation (1) | M. Florean Ministry of Environment and Climate Change, Romania

1. IMPEL: The European Union Network for the Implementation and Enforcement of Environmental Law
**Session 1: Nutrition**

**Presentations**

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T. Veldkamp, Wageningen UR, NL

Pig  
J.Y. Dourmad, INRA, Saint Gilles, France

IMPEL Presentation 1  
A. Holdsworth, Environmental Agency, UK

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### Session 1: Nutrition Discussion

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Main Impact</th>
<th>Knowledge/Application</th>
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<tbody>
<tr>
<td>Protein content</td>
<td>Reduction of $N_{excreted}$ and $NH_3$ emissions</td>
<td>++/+</td>
</tr>
<tr>
<td>Amino acid balance</td>
<td></td>
<td>++/+</td>
</tr>
<tr>
<td>Multiphase feeding</td>
<td></td>
<td>++/+</td>
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<tr>
<td>Dietary electrolyte balance</td>
<td></td>
<td>+/-</td>
</tr>
<tr>
<td>Additives</td>
<td></td>
<td>+/-</td>
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<tr>
<td>Enzymes</td>
<td></td>
<td>+/-</td>
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<tr>
<td>Fibrous feedstuffs (fermentable carbohydrates)</td>
<td>Modification of $N$, $C_{excreted}$ and $NH_3/CH_4$ emissions</td>
<td>++/-  ++/+</td>
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<td>Phosphorus</td>
<td>Reduction of $P_{excreted}$</td>
<td>++/+</td>
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<tr>
<td>Lipids</td>
<td>$CH_4$ decrease</td>
<td>++</td>
</tr>
<tr>
<td>Permanent grasslands</td>
<td>C sequestration increase</td>
<td>+</td>
</tr>
</tbody>
</table>
What is the expected level of reduction?

NH3: Göteborg Protocole → Draft guidance document

1% of reduction in protein content ⇒ decreased by 5 to 15% NH3 emissions from housing, manure storage and spreading (depending also on the pH of the urine and dung.)

**Target of the Annexe IX**

- option A: 15%
- option B: 10%
- option C: 5%

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What is the impact of diet modification on manure characteristics (volume produced, its dry matter, density, viscosity, C/N...) that could have an impact on the other BAT techniques used in housing, storage, treatment and spreading?

**Example:**

*"The High Fiber (HF) diet (pig) significantly increased the amount of faeces excreted by 40%, whereas the amount of urine was not affected. Concurrently, the HF diet significantly increased the C content of the faeces by 51% and the amount of OM excreted per pig by 65%, compared to the control diet."* Jarret et al, 2012
Session 2: Housing
Presentations

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<td>F.X. Philippe, University of Liège, Belgique</td>
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Session 2: Housing
Discussion

• Air emissions (NH₃, GHG (CH₄, N₂O), PM₂.₅/₁₀)
• Various mitigation techniques for air emissions but there are potential interference effects
• Which abatement technique should be used for which impact (air/soil/water)?
• Should the obligation to apply a technique be linked to the total emission from the farm (or groups of farms) or the impact from a specific building?
## Workshop agenda

### Wednesday 20th March 2013

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## Session 3: storage, treatment, spreading of manure

### Presentations

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Session 3: storage, treatment, spreading of manure

Discussion

- **Storage**
  - Few BAT relate to this step (mostly covers or additives)

- **Treatment of manure**
  - 14 treatments are listed with differing objectives
  - To be applied either as a unitary process or a combination of various processes with a given objective determined for every farm or group of farms depending on the local constrains and opportunities

- **Spreading**
  - BAT for NH$_3$ reduction with very few data on NO$_3^-$ or N$_2$O impact

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**What is the best way to greatly decrease the impact of livestock**

- An « overall » approach that needs integrated research (water+air+soil water expertise)
- A « farm by farm » approach according the emission level (but what level)
- An « step by step » approach (housing or storage or spreading focus) according the total emission of each step
- Do we need to focus the technique on housing?

---

**UK (Misselbrook et al, 2000)**

**France (Gac et al, 2007)**
General Discussion

A possible follow-on European project – producing a key reference book that includes:

- The compilation of results, statistic data (manure, livestock structures, …) on livestock research (Which funding source ?)
- Standard means to evaluate the environmental impact of a farm or farming area with respect to the main pollution types; to assign an overall impact that may be related to specific actions.
- Tool(s) to transpose International and European obligation according to national/regional context (to allow the European policy-maker to take account of the regional context of livestock).

Session 4: How to assess a BAT methodology

Presentations

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</table>
Session 4: How to assess a BAT

Discussion

- Measurement Techniques for Livestock Gas Emissions
  - Various methods to be adapted to the way the results are used: political (regulatory), scientific or certification use
  - A need for standardized reference method of measurement including error evaluation and uncertainties due to diffuse emissions
  - There is a need for Best Available Measurement Method (BAMM) to promote and to allow trustworthy emission measurement at the farm level

- BAT Assessment Tool
  - Life Cycle Analysis,
  - KTBL’s tool,
  - Vera’s tool,
  - Batfarm tool

Conclusions of the workshop

- There is a lot of scientific knowledge already available with some key reference papers on BAT
- But how much is really taken into account by policy-makers
- What actions can researchers working in the area change this situation for the better?
- Summary of main points arising ........
PP3

Reconciling the environment with livestock management

European Workshop – Rennes, France – 19/20 March 2013

www.batfarm.eu
DIRECTIVES

DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 24 November 2010
on industrial emissions (integrated pollution prevention and control)
(Recast)
(Revised with EEA relevance)

• Principle of preventing (and/or reducing) emissions to air, water and soil.

• Principle of BAT (Best Available Technique) as set out in BREF documents for each sector.

• For livestock, over 2000 places fattening pigs and 750 sow and over 40,000 places poultry need to be licensed.

FIG. 2. Distribution of the main livestock types in the EU-27. Animal density is expressed in livestock units (LU) per ha UAA, in which the relative weight of a mature dairy cow is set at 1 and the other livestock categories at 0.5 for beef cattle, 0.35 for pigs, 0.012 for meat birds and 0.018 for other poultry, respectively.
Large variations among EU countries

Diversity of livestock production systems

60-70% of livestock excreta collected in housing systems in EU

75% of European NH$_3$ emissions from livestock production
10% of total European GHG emissions due to livestock farming
Mean NH₃ and N₂O emission in kg N per ha agricultural land in EU-27 (Oenema O et al (2007) Livestock Science 112: 261-272)

Patterns of NH₃ and N₂O similar to spatial distribution of livestock

NH₃: Housing and storage

N₂O: direct soils from application of N fertilizer and animal manure

CH₄: Enteric fermentation and manure management

Fig. 6. Share of the different sectors of livestock production in total agricultural greenhouse gas emissions from each country. The countries on the x-axis are ordered according to the magnitude of greenhouse gas emissions.

Lesschen et al., 2011
Mitigation options

Production related / consumer-impacted

Livestock production
Livestock products consumption

Technical

1. Animal
2. Livestock housing
3. Manure storage and treatment
4. Field application
BAT’S

Rarely used due to:

- High cost

Manure treatment is still a minor manure management strategy in practice for economic reasons

The assessment of the emission reduction potential and economic cost/benefits of abatement technologies at farm level is required in order to assess the potential of manure management technologies to reduce national emissions

- Confusion of the benefits
- Lack of demonstration in commercially available farms
- BREF not applicable in all situations

What experiences are available?

How high are the expenses for the investment as well as the maintenance and operation of the systems?

What systems are suitable for different environmental purposes?

-Limited existence of user friendly decision support tools
Some of the BAT’S under experimental evaluation:

- Centrifugation and aerobic treatment of pig slurry
- Manure composting
- Phase feeding in laying hens
- Additives for ammonia and odours mitigation in slurry pits
- Aeration of slurry in underfloor slatted tanks
- Crusting of outdoor uncovered slurry tank
- Static modifications to reduce ammonia loss.
- Air scrubbers
- Psicrometric and heat exchange in broiler buildings
- Different systems for drying hen litter, etc…

Software’s stimations for each animal category on

**Housing:** Feeding, type of floor, slurry removal frequency, type of removal, other BAT’s

**Storage:** covers, additives…

**Treatment:** Separation, aerobic treatment, anaerobic treatment digestion, composting

**Landspreading:** trailing hose, trailing shoe, shallow injection, deep injection.
Thank you for your attention

www.batfarm.eu

pmerino@neiker.net
IMPEL projects

Comparison Programme on Permitting and Inspection of IPPC Pig Farming Installations in IMPEL Member Countries

Improving permitting and inspection of IPPC pig farming installations by developing practical guidance

BATFarm Workshop- Rennes, 19.03.2013

Manuela Florean
Ministry of Environment and Climate Change- National Environmental Guard
Hunedoara County Commissariat
Romania

IMPEL (The European Union Network for the Implementation and Enforcement of Environmental Law)

- International non-profit association of the environmental authorities of the EU Member States, acceding and candidate countries of the European Union and EEA countries. The association is registered in Belgium and its legal seat is in Bruxelles, Belgium
- IMPEL has the following Clusters: Improving Implementation of EU Environmental Law (Permitting, Inspection Enforcement and Smarter Regulation) and Cluster Transfrontier Shipment of Waste.
Comparison Programme on Permitting and Inspection of IPPC Pig Farming Installations in IMPEL Member Countries- 2009

General information about the project

- Participant countries: NL, LV, DE, FR, IT, PT, SE, CY, EE, IE, UK, PL, HU, RO, SK, SLO, CZ, DK
- 3 sites visits were made: Modena (IT), Riga (LV), Schwerin (DE)
- One workshop in Utrecht (NL)
- Participants filled in a questionnaire about IPPC pig farming; questionnaire generated 26 responses, with input from 26 authorities across 17 Member States
- A final report was issued in October 2009
Concerns raised by permitting and inspecting authorities relating to housing systems

- It is difficult for permitting authorities to determine what is BAT (SLO, FR, UK, EE).
- Access to, and understanding of information, is a problem (DK).
- Potential changes (e.g. cost) required to meet BAT and the associated timescales can be a problem (UK, Northern Ireland).
- Many farms have a range of housing systems on their farm. Many use straw-based solid floor systems - the acceptability of which is not covered in detail in the BREF (UK, England and Wales).
- The standard system is for deep slurry storage under slats. Operators argue that alternatives given in the BREF are expensive, not workable and would be difficult to establish as the building supply industry is not set up to use these (UK, Scotland).
- The flushing channel system is not considered to be BAT for new build systems. However, when changes take place on a farm it is not clear if the old flushing channel system still BAT or are the changes so big that it has to be considered as a new system and is not BAT (NL).

Concerns raised by permitting and inspecting authorities relating to abatement techniques

- The most common reason for the lack of air pollution abatement technology is the cost to the operators (DK, IE)
- The BREF provides little information on this issue and attempts to model specific emissions for sensitive receptors have proved to be very difficult, thus creating problems in defining what controls are needed (UK England and Wales)
- Difficulties to provide accurate estimations of emissions from different types of housing (FR, UK England and Wales)
- Application of BREFs is difficult (HU).
Concerns raised by permitting and inspecting authorities relating to manure storage and manure spreading

- The links between animal farming, agronomy and environment, especially for water quality (phosphorus and nitrogen). For example, there is no reliable control method which would guarantee the right balance of fertilization (FR).
- Difficulty to coordinate the application of some provisions, whose effects are opposite, such as provisions regarding manure treatment (which needs much energy) and measures to limit energy consumption (FR).
- There is a tension between methods used for reducing ammonia within units and quality of manure for spreading (FR).
- Availability of land for spreading slurry- Difficulty of providing adequate demonstration that slurry is being applied to land in accordance with crop nutrient requirements, in particular phosphorus; insufficient land available (UK Northern Ireland, RO, DE, PT).
- Making an accurate assessment of leaching potential in a specific area and an estimation of the effect of measures can be difficult (DK).

Other environmental issues identified by member states

- Odour- due to the close proximity of the pig farms to residential areas and dense concentration of large pig farms within some areas (CY, HU, UK Northern Ireland).
- Detection of odours can be complicated by local (and unrelated) landspreading and seasonality (UK, England and Wales).
- High concentrations of salts in the slurry causing problems in the use of slurry as fertiliser or for irrigation (CY).
- Eutrophication- how to deal with critical loads and how to evaluate the biotopes correctly with respect to their sensitivity to nitrogen and phosphorus (DE, DK).
- Ammonia emissions- Potential for damage to designated habitats –Application of ammonia abatement technology - cost prohibitive (UK Northern Ireland and Scotland).
- Difficulties to evaluate which is the most important: reduction of the amount of emitted ammonia gas or pig welfare considerations. I.e. the use of litter (straw) in pig housing systems is considered to be a good choice concerning pig welfare but the emission of ammonia gas is high compared to other housing systems (DK).
- Insufficient knowledge on impacts and transfer of veterinary medicines, detergents, disinfectants, etc. (DE).
- Air-washer in Germany-Schwerin

- Animal housing in Latvia-Riga
Lagoon system in Italy- Modena

Improving permitting and inspection of IPPC pig farming installations by developing practical guidance- 2011-2012
General information about the project

- Participant countries: NL, LV, LT, FR, IT, PT, CY, EE, IE, UK, PL, RO, SLO, CZ, ES, SE
- One site visit was carried out: Lisbon (PT)
- Two workshops in Utrecht (NL)
- Participants filled in a questionnaire in order to collect in depth information on problems or challenges related to IPPC pig farming, to provide an inventory of good examples of permitting and inspection tools that already has been developed, to make an inventory of need for common guidance that should be developed;
- An interim report was issued in November 2011
- The final report was issued in February 2013

Lagoon system in Portugal
Housing system for weaners on partly-slatted floor - Portugal

Relation with other European Directives

- Nitrates Directive (91/676/EEC)
- Habitats Directive (92/43/EEC)
Results of questionnaire

The questionnaires concluded that there is need for more guidance like:

- How to work with the BREF?
- Inspection guidance in case of complaints
- How to do an odour management assessment?
- How to do a fly management assessment?
- Assessment of BAT for housing
- Inspection instruction specific for pig sector

Problems that came up are:

- The determination of what is BAT due to many different building types/designs and slurry systems
- As there is no ELV settle in BAT, it is difficult to establish quantitative targets and performance indicators.
- Difficult to validate/confirm the actual numbers of pigs on farms due to the differing stages of production; different pig weight ranges, etc
- Behaviour of pig farmers, most of them are independent, not educated.
- Sector economical situation
Inspection guidance book for intensive piggeries

- Pigs in housing
- Manure storage (slurry)
- Manure spreading on own land
- Storage of waste
- Feed storage
- Transportation
- On-farm manure treatment
- Waste water treatment
- Storage of carcases
- Feed mixing
- Storage of liquid manure fraction
- Storage of solid manure
- Storage of dangerous substances (Diesel, Fertilizer)
- Inspection preparation
  - Which information should be collected?
  - What should be clear?
- On site inspection: Checklists for the major activities and general tips
- After inspection

Thank you!
Decreasing environmental impacts from cattle through nutrition: what may be the best available techniques?

- Available now
- Without major changes in farming systems

Michel Doreau¹, Philippe Faverdin², Katja Klumpp³

¹INRA/VetagroSup, UMR 1213 Herbivores, 63122 Saint-Genès Champanelle, France
²INRA/Agrocampus Ouest, UMR 1348 Pegase, 35590 Saint-Gilles, France
³INRA, UR 874 Grassland Ecosystem Research 63100 Clermont-Ferrand, France

GHG emissions of French cattle farms (eq-CO₂) by LCA approach

**BEEF**

- Methane: 45 – 60%
- Nitrous oxide: 25 – 35%
- Carbon dioxide: 10 – 25%

**DAIRY**

- Methane: 100%
- Nitrous oxide: 25 – 35%
- Carbon dioxide: 10 – 25%

Nguyen et al., 2012, 2013
1. Mitigating enteric methane production
2. Decreasing organic matter and N losses
3. Optimizing grassland use
### Biotechnology

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Efficiency and possible use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removing protozoa</td>
<td>Efficient; mode of defaunation to be found</td>
</tr>
<tr>
<td>Adding yeast, propionate-enhancers bacteria</td>
<td>In vivo trials requested</td>
</tr>
<tr>
<td></td>
<td><strong>Additional research needed, could be used in the short term</strong></td>
</tr>
<tr>
<td>Adding acetogens</td>
<td>In vitro effect of kangaroo bacteria</td>
</tr>
<tr>
<td>Vaccination</td>
<td>Effect to be confirmed</td>
</tr>
<tr>
<td>Antibodies</td>
<td>In vitro transient effect</td>
</tr>
</tbody>
</table>

Long and complex research needed, might be used in the long term
# Additives

<table>
<thead>
<tr>
<th>Antibiotics</th>
<th>Cellulolytic bacteria</th>
<th>May be efficient but forbidden in the EU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemicals (chloroform,..)</td>
<td>Methanogens</td>
<td>In vitro effect, often toxic</td>
</tr>
</tbody>
</table>

### No

<table>
<thead>
<tr>
<th>Plant extracts (tannins, saponins)</th>
<th>Methanogens</th>
<th>Protozoa</th>
<th>In vitro effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic acids</td>
<td>Hydrogen user</td>
<td>Action on microbes ?</td>
<td>High amount requested, acidity, cost</td>
</tr>
</tbody>
</table>

Further research needed, could be used in the short term

| Nitrate | Hydrogen user | Efficient in vivo but potential risk for animal |

Yes ?

---

# Nitrate as mitigating agent

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Proven to be efficient</td>
<td>• Poor image of « nitrate »</td>
</tr>
<tr>
<td>• At the right dose, no increase in other GHG</td>
<td>• Risk of nitrite accumulation and animal death</td>
</tr>
<tr>
<td>• Not expensive (hope…)</td>
<td>• Possible increase in urinary N</td>
</tr>
</tbody>
</table>

⇒ Control of dose
⇒ For diets poor in fermentable N
**Diet composition**

<table>
<thead>
<tr>
<th>High-concentrate diets</th>
<th>Target</th>
<th>Efficiency and possible use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulolytic bacteria</td>
<td></td>
<td>Efficient, especially when more than 60% concentrates</td>
</tr>
<tr>
<td>Protozoa</td>
<td></td>
<td>Partial compensation for other GHG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Possible health problems (acidosis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cereals: competition with human food</td>
</tr>
</tbody>
</table>

**Lipids**

<table>
<thead>
<tr>
<th>Replace CHO</th>
<th>Cellulolytic bacteria</th>
<th>Protozoa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Replace CHO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Efficiency, depending on source</td>
<td>Partial compensation for other GHG</td>
</tr>
</tbody>
</table>

**Not recommended (French conditions)**

**Dietary lipids**

- **CH4 % control**

- **% lipid supplement**

- **Linoleic acid** (soybean, sunflower)
- **Linolenic acid** (linseed)
- **Lauric and myristic acids** (coconut, palm kernel)

- **Recommended (omega-3 FA)**
- **Not recommended** (medium-chain saturated FA)

_Oleaginous seeds replace cereals: partial compensation for total GHG_

*Doreau et al., 2011*
1. Mitigating enteric methane production

2. Decreasing organic matter and N losses

3. Optimizing grassland use

<table>
<thead>
<tr>
<th>Mitigation of enteric CH4</th>
<th>Effect on undigestible carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-concentrate diets</td>
<td></td>
</tr>
<tr>
<td>Lipids</td>
<td></td>
</tr>
<tr>
<td>Tannins</td>
<td></td>
</tr>
<tr>
<td>Other additives (including nitrate) and biotechnologies</td>
<td></td>
</tr>
</tbody>
</table>
Dairy cows on pasture

N fertilizer (kg/ha/an)  60  300
N in grass (g/kg MS)  17  24
N in milk (g/kg MS)  6  6
N in faeces (g/kg MS)  6  6
N in urine (g/kg MS)  5  12

Peyraud and Astigarraga, 1998

Kebreab et al., 2001
Providing rumen-protected N sources

Formaldehyde-treated meals (soybean, rapeseed)

- Ruminal protection decreases ruminal degradation and N waste as ammonia
- Requires nutritional control by the farmer
- Not widely spread

Protected amino acids (lysine, methionine)

- Ruminal protection prevents ruminal degradation
- Provides essential amino acids for milk and meat
- Use is limited by the cost

Decreasing dietary N in dairy when applicable

Pros

- Efficient until 14% CP in the diet (often 16-17% now)
- Easy to implement using feeding systems
- Easy to monitor using milk urea
- Farmer spares money (win-win strategy)

Cons

- Farmers prefer N overfeeding to prevent risks of milk yield decrease

210 mg/l

Faverdin and Vérité, 1998
1. *Mitigating enteric methane production*

2. *Decreasing organic matter and N losses*

3. *Optimizing grassland use*

---

**A model among others**

- New methodology accounts for storage in deep soil layers
- High variability depending on climate, plant biomass, grazing vs cut, ploughing
- When taken into account for C balance: 0.12 to 2.5 T C/ha per year

*Arrouays et al. (2002)*
Changing grassland usage

Increasing time at pasture

- More C storage in soil with grazing than with mowing
- Less manure storage and probably less GHG and NH₃ emissions, more C recycled when grazing
- When and where it is possible (max. 20 days more in France)

Increasing temporary pastures lifetime

- Less ploughing thus less C release from soil
- N binds to soil organic matter: less NO₃ leaching, less NH₃ and N₂O emissions

Changing grassland management

Decreasing N fertilizers

- Less N mineral fertilizers (often excessive in France) – May be a win-win strategy
- Increasing part of legumes

Stocking rate: a contrasted effect

- A high stocking rate:
  - Tends to increase C storage because of more recycled organic matter
  - But tends to decrease C storage because of more biomass exportation
- On average extensive systems store more C than intensive systems
GHG balance on pasture

<table>
<thead>
<tr>
<th>Allard et al, 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive management</td>
</tr>
<tr>
<td>High stocking rate, fertilizers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CH₄ (g/kg weight gain)</th>
<th>287</th>
<th>296</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄ (kg C-eq / ha)</td>
<td>820</td>
<td>420</td>
</tr>
<tr>
<td>N₂O (kg C-eq / ha)</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>CO₂ (kg C-eq / ha)</td>
<td>-990</td>
<td>-750</td>
</tr>
<tr>
<td>Balance (kg C-eq / ha)</td>
<td>-100</td>
<td>-310</td>
</tr>
</tbody>
</table>

Concluding remarks

- The present choices have been made by « experts »; other experts in other countries may have other proposals
- This expertise is in progress; the number of animals concerned by each option and the cost for implementation have to be evaluated
- Interactions between options are difficult to quantify
- These options do not require major changes in farming systems and can thus be accepted by farmers; public policies should support their implementation
Thank you
Reduction of ammonia emission from poultry houses by nutritional tools

European workshop: applying Best Available Techniques on the FARM (BATFARM) 19 March 2013

Dr. Teun Veldkamp

Introduction

- Ammonia emission in agriculture contributes almost 50% in total nitrogen deposition in The Netherlands (Haan et al., 2008)
- From 2010 – 2030 special attention to:
  - Improving spread of manure in arable farming (injection of manure)
  - Intensify emission requirements for housing (level of Best Available Techniques)
  - Additional: nutrition and management tools next to housing tools
Aim

- The Ministry of Economic Affairs asked Wageningen UR Livestock Research to conduct a desk study on the role of nutrition in ammonia emission
- The aim of the study was to describe nutritional tools that may reduce ammonia emission in poultry (laying hens, broilers, parent stock, ducks and turkeys) and to estimate the effect on ammonia emission
- No adverse effects on odour, fine dust, nitrous oxide, methane and energy consumption

Nitrogen in poultry excreta

- Nitrogen utilisation by poultry is 35% (Schutte and Tamminga, 1992).
- Undigested proteins and uric acid contribute 30 and 70% to the total nitrogen content in excreta, respectively
- Undigested proteins were not used by the animal while uric acid is generated from the surplus of nitrogen in the animal
- Total urine N in poultry (Krogdahl and Dalsgard, 1981):
  - 88% originates from uric acid
  - 7% originates from ammonia
  - 3% originates from urea
  - 2% is not identified
Why is drying of excreta important?

- After excretion micro-organisms transform uric acid and undigested protein into:
  - urea ($\text{CH}_4\text{N}_2\text{O}$), ammonia ($\text{NH}_3/\text{NH}_4^+$), nitrite ($\text{NO}_2^-$), nitrate ($\text{NO}_3^-$), nitrous oxide ($\text{N}_2\text{O}$), nitrogen-monoxide ($\text{NO}$), nitrous gas ($\text{N}_2$) and microbial protein
- Microbial degradation of proteins and uric acid into urea and subsequently ammonia is the most important process
- This microbial degradation depends on water content of the excreta
- Most of the ammonia reduction techniques are based on a quick drying of excreta/manure

Nutritional tools to decrease ammonia emission

- Phase feeding
- Crude protein and free amino acids
- Enzymes
- Dietary electrolyte balance
- Phosphorus
- Fermentable carbohydrates
- Feed additives
Phase feeding

- Phase feeding is to adjust the nutrient supply to the nutrient requirement during the production period in order to avoid a surplus of protein and amino acids
- Reducing the excretion of uric acid
- Reducing the risk for transforming uric acid into ammonia
- The more phases the more accurate nutrient supply

### Standard feeding phases and crude protein content per poultry species

<table>
<thead>
<tr>
<th>Laying hens</th>
<th>Age (wk)</th>
<th>0-4</th>
<th>5-8</th>
<th>9-16</th>
<th>17-20</th>
<th>20-28</th>
<th>29-45</th>
<th>46-65</th>
<th>&gt;65</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP (%)</td>
<td></td>
<td>21.0</td>
<td>18.5</td>
<td>14.5</td>
<td>17.5</td>
<td>18.0</td>
<td>19.6</td>
<td>18.4</td>
<td>17.8</td>
</tr>
<tr>
<td>Broiler chickens</td>
<td>Age (wk)</td>
<td>0-10</td>
<td>11-28</td>
<td>29-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (%)</td>
<td></td>
<td>22.0</td>
<td>21.0</td>
<td>19.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broiler breeders</td>
<td>Age (wk)</td>
<td>0-2</td>
<td>3-6</td>
<td>7-15</td>
<td>16-22</td>
<td>23-40</td>
<td>41-60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (%)</td>
<td></td>
<td>20.0</td>
<td>18.0</td>
<td>14.0</td>
<td>15.0</td>
<td>15.0</td>
<td>14.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turkeys</td>
<td>Age (wk)</td>
<td>0-2</td>
<td>3-5</td>
<td>6-9</td>
<td>10-13</td>
<td>14-17</td>
<td>18-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (%)</td>
<td></td>
<td>27.5</td>
<td>26.0</td>
<td>23.5</td>
<td>21.0</td>
<td>18.0</td>
<td>16.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ducks</td>
<td>Age (wk)</td>
<td>0-2</td>
<td>&gt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP (%)</td>
<td></td>
<td>17.2</td>
<td>14.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Age at 5% production level is realised.
Phase feeding in laying hens

Phase feeding in laying hens based on digestible lysine content in diets; calculated dLys requirement based on production of ISA Brown.

- Phase feeding in three periods as usual for a long time in practice (phase 1 and 2 only differ in calcium content, not in protein content).
- Phase feeding in six periods based on dLys requirement model.

No studies on effect of phase feeding in laying hens on NH3.

Effect of phase feeding (PF) and crude protein content on performance, protein intake and nitrogen excretion in broilers (21-63 d of age)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Treatment</th>
<th>Age (d)</th>
<th>NRC</th>
<th>PF standard</th>
<th>PF low protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein content (%)</td>
<td></td>
<td>21-43</td>
<td>19.8</td>
<td>21.5</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>17.6</td>
<td>15.6</td>
<td>15.0</td>
</tr>
<tr>
<td>ME (kcal/kg)</td>
<td></td>
<td>21-43</td>
<td>3114</td>
<td>3062</td>
<td>3109</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>3169</td>
<td>3218</td>
<td>3256</td>
</tr>
<tr>
<td>BW gain (g)</td>
<td></td>
<td>21-63</td>
<td>3473</td>
<td>3185</td>
<td>3446</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>3473</td>
<td>3185</td>
<td>3446</td>
</tr>
<tr>
<td>Feed intake (g)</td>
<td></td>
<td>21-63</td>
<td>7875</td>
<td>7442</td>
<td>7852</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>7875</td>
<td>7442</td>
<td>7852</td>
</tr>
<tr>
<td>Feed conversion ratio (g/g)</td>
<td></td>
<td>21-63</td>
<td>2.267</td>
<td>2.337</td>
<td>2.279</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>2.307</td>
<td>2.307</td>
<td>2.279</td>
</tr>
<tr>
<td>Crude protein intake (g)</td>
<td></td>
<td>21-43</td>
<td>710</td>
<td>659</td>
<td>676</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>728&lt;sup&gt;a&lt;/sup&gt;</td>
<td>674&lt;sup&gt;a&lt;/sup&gt;</td>
<td>672&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-63</td>
<td>1438</td>
<td>1333</td>
<td>1348</td>
</tr>
<tr>
<td>N excretion (g)</td>
<td></td>
<td>21-43</td>
<td>50.1</td>
<td>50.9</td>
<td>50.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>50.1</td>
<td>50.9</td>
<td>50.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-63</td>
<td>59.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43-63</td>
<td>59.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21-63</td>
<td>109.4</td>
<td>105.1</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Results in a row differing in superscript are significantly different (P < 0.05).

(Pope et al., 2004)

Angel et al. (2008) 6 PF vs. 4 PF resulted in 22% reduction NH3.
Crude protein and free amino acids

- Nitrogen utilisation depends on the digestibility of crude protein, the amino acid profile, the digestibility of amino acids and the nitrogen requirement
- A surplus of protein and amino acids should be avoided
- Reducing the excretion of uric acid
- Reducing the risk for transforming uric acid into ammonia
- Decrease of water intake and effects on moisture content of excreta/litter

Crude protein and free amino acids
Laying hens

- Literature is scarce
- 3 – 3.5% reduction in crude protein content (16.5 vs. 13.0% CP) resulted in 45% reduction in nitrogen excretion (with supplementation of free amino acids) (Keshavarz and Austic, 2004). Feed costs twice as high
- 1% reduction in crude protein content resulted in 10% reduction in nitrogen excretion (Roberts et al., 2007)
Crude protein and free amino acids
Broilers

- 23.0, 22.5, 20.0% CP vs. 23.0, 19.5, 18.0% CP in starter, grower and finisher diets, respectively resulted in 11% reduction in feed intake, 16% reduction in nitrogen excretion and 66% reduction in NH₃ (van Harn and van Middelkoop, 1996)
- 20 g/kg lower crude protein content resulted in 15% reduction in nitrogen excretion (Gates et al., 2000)
- 21.5% CP vs. 19.6% CP in finisher diet resulted in 16.5% reduction in nitrogen excretion and 31% reduction in NH₃ (Ferguson et al., 1998)
- 22% CP vs. 18% CP in finisher diet resulted in 30% reduction in NH₃ (Elwinger and Svenson, 1998)

Performance and nitrogen excretion of broilers (0-46 days of age) fed a standard diet or a low CP diet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Standard diet</th>
<th>Low protein diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight gain (g)</td>
<td>3194</td>
<td>3271</td>
</tr>
<tr>
<td>Feed intake (g)</td>
<td>5619</td>
<td>5658</td>
</tr>
<tr>
<td>Feed conversion ratio (g/g)</td>
<td>1.762</td>
<td>1.732</td>
</tr>
<tr>
<td>N-excretion (g/broiler)</td>
<td>65.43ₐ</td>
<td>56.87ₐ</td>
</tr>
</tbody>
</table>

13.1% reduction

Standard diet: 260, 221, 210, 200 and 192 g CP/kg
Low protein diet: 245, 208, 198, 188 and 180 g CP/kg
In age periods (d): 1-8, 8-21, 21-33, 33-40 and 40-46, respectively

(Lora et al., 2008)
**Amino acid content in two diets for laying hens based on a formulation with maize, soybean meal and DL-methionine (Feed A: 18.1% CP) or formulated with maize, soybean meal, DL-methionine, L-Lysine.HCl, and L-Threonine (Feed B: 16.1% CP). Both diets met the amino acid requirement but surplus of amino acids in Feed B was lower (Bregendahl and Roberts, 2006)**

**Enzymes**

- To increase the nutritional value of feed ingredients (digestibility of CP and amino acids)
- Examples: phytase (phosphorus), viscosity decreasing enzymes (xylanase, β-glucanase), protease (protein/amino acids)
- i.e. Possibility to decrease CP content in diets by use of enzymes
Enzymes

Effect of phytase and xylanase in low-P diets on performance and nitrogen retention in broilers (0-21 d of age)

<table>
<thead>
<tr>
<th>Diet</th>
<th>Body weight gain (g)</th>
<th>Feed intake (g)</th>
<th>Feed conversion (g/g)</th>
<th>N-retention (g/kg DM intake)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>818a</td>
<td>1247a</td>
<td>1.536a</td>
<td>21.2b</td>
</tr>
<tr>
<td>Low P</td>
<td>718b</td>
<td>1088b</td>
<td>1.515b</td>
<td>21.4c</td>
</tr>
<tr>
<td>Low P + xylanase</td>
<td>743b</td>
<td>1050b</td>
<td>1.421d</td>
<td>22.6p</td>
</tr>
<tr>
<td>Low P + phytase</td>
<td>838a</td>
<td>1231a</td>
<td>1.477c</td>
<td>23.7p</td>
</tr>
<tr>
<td>Low P + xylanase + phytase</td>
<td>861a</td>
<td>1207a</td>
<td>1.456d</td>
<td>23.8p</td>
</tr>
</tbody>
</table>

a-d Results in column differing in superscript are significantly different (P < 0.05)

(Selle et al., 2009)

Enzymes

Effect of different dose levels of protease on nitrogen digestibility in males of Lohmann Brown laying hen strain

(Selz et al., 2003)
Dietary electrolyte balance

- Water intake is affected by dietary contents of sodium (Na), chloride (Cl) and potassium (K) and as a consequence moisture content in excreta/litter will be affected.
- Most feed ingredients are low in Na and Cl.
- Potassium content is often higher than requirement of poultry (soybean meal).
- Balance between electrolytes is important for physiological regulation of osmotic pressure and acid-base balance.
- Lower DEB $\rightarrow$ lower blood pH $\rightarrow$ lower urine pH $\rightarrow$ lower excreta pH $\rightarrow$ NH$_3$ transformation into NH$_4$ $\rightarrow$ NH$_4$ is water soluble $\rightarrow$ reduction of NH$_3$.

Dietary electrolyte balance

Laying hens

Effect of sodium and potassium content on water intake, feed intake, water/feed ratio, excreta and excreta moisture in laying hens

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sodium content in diet (g/kg)</th>
<th>SEM</th>
<th>Potassium content in diet (g/kg)</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water intake (g/d)</td>
<td>1,5</td>
<td>5,5</td>
<td>9,4</td>
<td>13,2</td>
</tr>
<tr>
<td>Feed intake (g/d)</td>
<td>113</td>
<td>100</td>
<td>93</td>
<td>74</td>
</tr>
<tr>
<td>Water/feed ratio</td>
<td>1,43</td>
<td>2,19</td>
<td>3,21</td>
<td>4,94</td>
</tr>
<tr>
<td>Excreta production (g/d)</td>
<td>72</td>
<td>100</td>
<td>133</td>
<td>141</td>
</tr>
<tr>
<td>Moisture content excreta</td>
<td>698</td>
<td>790</td>
<td>810</td>
<td>844</td>
</tr>
</tbody>
</table>

- For all parameters a significant linear effect of sodium and potassium was reported ($P < 0.001$).
Dietary electrolyte balance

Broilers

Effect of DEB on litter score and DM content in broilers of 21 d of age

DEB = dietary electrolyte balance

Litter score: score 1 = "good quality, high DM content" and score 5 = "bad quality, low DM content"

(Smith et al., 2000)

Dietary electrolyte balance

Broilers

Effect of DEB on moisture content in litter of broilers at 21 d of age

DEB = dietary electrolyte balance

(Smith et al., 2000)
Phosphorus
Laying hens

Effect of phosphorus content on water intake, feed intake, water/feed ratio, excreta and excreta moisture in laying hens

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Phosphorus content in diet (g/kg)</th>
<th>SEM*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water intake (g/d)</td>
<td>225  235  244  252  257  347</td>
<td>51</td>
</tr>
<tr>
<td>Feed intake (g/d)</td>
<td>135  142  148  152  147  147</td>
<td>23</td>
</tr>
<tr>
<td>Water/feed ratio</td>
<td>1.73  1.60  1.52  1.66  1.77  2.41</td>
<td>0.41</td>
</tr>
<tr>
<td>Excreta production (g/d)</td>
<td>106  116  117  117  123  183</td>
<td>27</td>
</tr>
<tr>
<td>Moisture content excreta (g/kg)</td>
<td>711  716  724  729  744  808</td>
<td>23</td>
</tr>
</tbody>
</table>

*For water intake and moisture content in excreta a significant effect (P < 0.001); for water/feed ratio a significant effect (P < 0.01)

(Smith et al., 2000)

Fermentable carbohydrates

- Fermentable carbohydrates are not digested but degraded by bacteria in the colon
- Bacteria require nitrogen for protein synthesis
- Fecal nitrogen will be excreted as microbial protein
- Microbial protein will not be transformed into NH3 (Bregendahl and Roberts, 2006)
- Microbial fermentation results in more volatile fatty acids → decrease of pH
- Disadvantage: Decrease of nutrient digestibility
**Fermentable carbohydrates**

**Laying hens**

Effect of inclusion of 5% soyhulls, 7% wheat middlings or 10% maize DDGS in laying hen diets on ammonia emission

![NH3 emission graph](image)

* Significantly different compared to standard (P < 0.01)

(Roberts et al., 2007)

---

**Feed additives**

- Bacillus subtilis culture
- Lactobacillus
- Yeasts
- Algae
- Clay minerals
- Acidifying Ca sources (CaSO₄ or CaCl₂)
- Yucca product
Effect nutritional tools on costs laying hen diets

<table>
<thead>
<tr>
<th>Nutrients (g/kg)</th>
<th>Standard</th>
<th>-30 g/kg CP+18 g/kg NSP</th>
<th>30 g/kg CP-18 g/kg NSP +18 g/kg NSP</th>
<th>28 g/kg CP-18 g/kg NSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME (kcal/kg)</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
<td>2800</td>
</tr>
<tr>
<td>Dry Matter</td>
<td>884</td>
<td>884</td>
<td>887</td>
<td>890</td>
</tr>
<tr>
<td>CP</td>
<td>163</td>
<td>160</td>
<td>165</td>
<td>168</td>
</tr>
<tr>
<td>CFAT</td>
<td>28</td>
<td>30</td>
<td>38</td>
<td>55</td>
</tr>
<tr>
<td>CFIBRE</td>
<td>21</td>
<td>19</td>
<td>25</td>
<td>29</td>
</tr>
<tr>
<td>NSP1</td>
<td>122</td>
<td>115</td>
<td>140</td>
<td>160</td>
</tr>
<tr>
<td>Ca</td>
<td>36.0</td>
<td>37.2</td>
<td>36.0</td>
<td>36.0</td>
</tr>
<tr>
<td>P</td>
<td>4.5</td>
<td>4.4</td>
<td>4.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Op</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Na</td>
<td>1.3</td>
<td>1.5</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>K</td>
<td>6.5</td>
<td>4.4</td>
<td>6.4</td>
<td>7.0</td>
</tr>
<tr>
<td>Cl</td>
<td>2.1</td>
<td>2.8</td>
<td>2.1</td>
<td>2.0</td>
</tr>
<tr>
<td>d.Lys</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
<td>6.8</td>
</tr>
<tr>
<td>d.M+C</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>d.Thr</td>
<td>4.9</td>
<td>5.0</td>
<td>4.8</td>
<td>4.9</td>
</tr>
<tr>
<td>d.Trp</td>
<td>1.5</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Costs compared to standard</td>
<td>100%</td>
<td>116%</td>
<td>101%</td>
<td>103%</td>
</tr>
</tbody>
</table>

Effect nutritional tools on costs broiler diets

<table>
<thead>
<tr>
<th>Nutrients (g/kg)</th>
<th>Standard</th>
<th>-5 g/kg CP-10g/kg CP</th>
<th>-15 g/kg CP</th>
<th>+9 g/kg NSP+19 g/kg NSP</th>
<th>-0.5 g/kg K-1.0 g/kg K</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME (kcal/kg)</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Dry Matter</td>
<td>878</td>
<td>880</td>
<td>879</td>
<td>880</td>
<td>881</td>
</tr>
<tr>
<td>CP</td>
<td>205</td>
<td>200</td>
<td>195</td>
<td>202</td>
<td>198</td>
</tr>
<tr>
<td>CFAT</td>
<td>78</td>
<td>80</td>
<td>77</td>
<td>80</td>
<td>79</td>
</tr>
<tr>
<td>CFIBRE</td>
<td>27</td>
<td>33</td>
<td>38</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>NSP1</td>
<td>152</td>
<td>154</td>
<td>156</td>
<td>161</td>
<td>137</td>
</tr>
<tr>
<td>Ca</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>P</td>
<td>5.0</td>
<td>5.1</td>
<td>5.1</td>
<td>5.0</td>
<td>5.2</td>
</tr>
<tr>
<td>Op</td>
<td>3.3</td>
<td>3.4</td>
<td>3.4</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Na</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>K</td>
<td>9.0</td>
<td>8.4</td>
<td>7.5</td>
<td>8.6</td>
<td>7.9</td>
</tr>
<tr>
<td>Cl</td>
<td>2.6</td>
<td>2.7</td>
<td>2.9</td>
<td>2.6</td>
<td>2.7</td>
</tr>
<tr>
<td>d.Lys</td>
<td>10.2</td>
<td>10.2</td>
<td>10.2</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>d.M+C</td>
<td>7.4</td>
<td>7.4</td>
<td>7.4</td>
<td>7.4</td>
<td>7.4</td>
</tr>
<tr>
<td>d.Thr</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
<td>6.6</td>
</tr>
<tr>
<td>d.Trp</td>
<td>2.2</td>
<td>2.1</td>
<td>2.0</td>
<td>2.1</td>
<td>2.0</td>
</tr>
<tr>
<td>Costs compared to standard</td>
<td>100%</td>
<td>105%</td>
<td>112%</td>
<td>119%</td>
<td>106%</td>
</tr>
</tbody>
</table>
Conclusion

- Reduction of ammonia emission is possible by nutritional tools and keeping up health and performance of poultry
- Nutritional tools are useful to increase nitrogen utilisation, decrease nitrogen excretion and decrease ammonia emission separately as a tool or in combination with housing and management tools
- Nutritional tools are not yet implemented in regulation of ammonia emission

Questions and Discussion

Should European or National authorities include nutritional tools in legislation with regard to ammonia emission?
Pig nutrition: impact on N, P, Cu and Zn in pig manure and on emissions of ammonia, greenhouse gases and odours

Jean-Yves Dourmad¹, Florence Garcia-Launay¹, Agnes Narcy²
¹INRA Agrocampus Ouest, UMR Pegase
²INRA, UR Recherches Avicoles

Effect of nutrition on nutrient flow in pig production

- Reduction of excretion of nitrogen
  - Reduction of ammonia emissions
  - Effect on emissions of greenhouse gases
  - Reduction of excretion of Phosphorus
  - Reduction of excretion of trace elements
Efficiency of N utilization in growing pigs

- Protein intake [100]
- Protein retention [32]
- Absorbed amino acids
  - obligatory oxidation
  - oxidation of a.a in excess
- Faecal excretion [16]
- Urinary excretion [51]
- Manure [68]

Effect of phase feeding and protein quality on N excretion by fattening pigs

- Excretion, % of control
  - One-phase: 17.5 - 15.0%, 17.5 - 15.0%, 16.0 - 13.5%, 17.5 => 15.0 => 13.0 => 12.0 => 11.0%
  - Two-phase: 17.5 - 15.0%, 17.5 - 15.0%, 16.0 - 13.5%, 17.5 => 15.0 => 13.0 => 12.0 => 11.0%
  - Multiphase: 17.5 - 15.0%, 17.5 - 15.0%, 16.0 - 13.5%, 17.5 => 15.0 => 13.0 => 12.0 => 11.0%

Corpen
Reduction of N excretion, actual situation in France and perspectives

<table>
<thead>
<tr>
<th></th>
<th>Corpen, 2003</th>
<th>Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Two-phase</td>
</tr>
<tr>
<td>Crude protein, g/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestation</td>
<td>170</td>
<td>140</td>
</tr>
<tr>
<td>Lactation</td>
<td>170</td>
<td>165</td>
</tr>
<tr>
<td>Pre-starter</td>
<td>210</td>
<td>200</td>
</tr>
<tr>
<td>Starter</td>
<td>190</td>
<td>180</td>
</tr>
<tr>
<td>Grower</td>
<td>175</td>
<td>165</td>
</tr>
<tr>
<td>Finisher</td>
<td>175</td>
<td>150</td>
</tr>
<tr>
<td>Average</td>
<td>177</td>
<td>158</td>
</tr>
</tbody>
</table>

N per slaughter pig (0-115 kg)

<table>
<thead>
<tr>
<th></th>
<th>Intake</th>
<th>Retention</th>
<th>Excretion</th>
<th>% of standard</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.10</td>
<td>2.89</td>
<td>6.06</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>8.16</td>
<td>2.89</td>
<td>5.13</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>7.23</td>
<td>2.89</td>
<td>4.22</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>6.78</td>
<td>2.89</td>
<td>3.78</td>
<td>63</td>
</tr>
</tbody>
</table>

Evolution of average N excretion per kg pig produced in France

- 35%
Effect of nutrition on nutrient flow in pig production

- Reduction of excretion of nitrogen
- ✓ Reduction of ammonia emissions
- Effect on emissions of greenhouse gases
- Reduction of excretion of Phosphorus
- Reduction of excretion of trace elements

Volatilization of ammonia from slurry

- Urea
- NH$_4^+$
- NH$_3$ (gas)
- NH$_3$ (air)
- pH
- Henry constant
- Temperature
- Mass transfer coefficient
- Air speed

Reduction of volatilisation of N compounds

- **Factors affecting emissions** (liquid slurry)
  - $[\text{NH}_3]$, pH, air renewal, type of floor…
  - Can be manipulated through feeding
    - CP content => $[\text{NH}_3]$ and pH
    - Electrolyte balance ($\text{Na}^+ + \text{K}^+ - \text{Cl}^- - \text{S}^-$) => affect urinary pH
    - Supplementation with acids or salts => affect urinary pH
    - Addition of NSP => production of VFA => affect pH

Effect of CP on slurry characteristics and ammonia volatilisation in fattening pigs

<table>
<thead>
<tr>
<th>Slurry composition</th>
<th>Dietary crude protein content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
</tr>
<tr>
<td>Amount, kg/d</td>
<td>5.7</td>
</tr>
<tr>
<td>DM, %</td>
<td>4.4</td>
</tr>
<tr>
<td>Total Kjeldahl N (g N kg$^{-1}$)</td>
<td>5.48</td>
</tr>
<tr>
<td>Ammoniacal N (g N kg$^{-1}$)</td>
<td>4.32</td>
</tr>
<tr>
<td>pH</td>
<td>8.92</td>
</tr>
<tr>
<td>N balance (g pig$^{-1}$ d$^{-1}$)</td>
<td>Retention</td>
</tr>
<tr>
<td></td>
<td>Excretion</td>
</tr>
<tr>
<td></td>
<td>Ammonia volatilization</td>
</tr>
<tr>
<td></td>
<td>Soil (available for plants)</td>
</tr>
</tbody>
</table>

*Portejoie et al., 2005*
Effect of fibre content in fattening pigs diet on composition of excreta, N balance and ammonia emission

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>High-fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Fiber, g/kg</td>
<td>29.4</td>
<td>49.0</td>
</tr>
<tr>
<td>N balance, g/d</td>
<td>55.9</td>
<td>55.5</td>
</tr>
<tr>
<td>Intake</td>
<td>28.7</td>
<td>30.3</td>
</tr>
<tr>
<td>Excretion</td>
<td>26.3</td>
<td>40.0 ***</td>
</tr>
<tr>
<td>% in faeces</td>
<td>28.7</td>
<td>30.3</td>
</tr>
<tr>
<td>pH urine</td>
<td>8.28</td>
<td>7.15 ***</td>
</tr>
<tr>
<td>pH faeces</td>
<td>8.39</td>
<td>8.11 ***</td>
</tr>
<tr>
<td>VFA in faeces, mg/L</td>
<td>62.6</td>
<td>260.0 ***</td>
</tr>
<tr>
<td>Ammonia emission (% excretion)</td>
<td>17.9</td>
<td>12.4 ***</td>
</tr>
</tbody>
</table>

Jarret et al., 2011

Effect of dietary protein content (18 or 13%) and addition of benzoic acid (+ ou -) on ammonia volatilization (cumulated emission during 10 d)

Daumer et al., 2007
Effect of nutrition on nutrient flow in pig production

- Reduction of excretion of nitrogen
- Reduction of ammonia emissions
- Effect on emissions of greenhouse gases
- Reduction of excretion of Phosphorus
- Reduction of excretion of trace elements

Effect of feeding on emissions of GHG

- Enteric emission of CH$_4$
  - $CH_4$ Enteric = f (digestible fibre)
  - digFiber = digOM – digProt – digFat – Starch - Sugar

- Effluent emission of CH$_4$
  - $CH_4$ Manure (kg) = VS x $B_0$ x FCM
  - VS => indigestible OM => depends on the feed
  - $B_0$ : potential CH$_4$ emission
  - MCF : methane conversion factor

- N$_2$O emission
  - N excreted * EF
Effect of fibre content in fattening pigs diet on volatile solid of excreta (VS), composition of excreta, N balance and ammonia emission

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>High-fibre*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Fibre, g/kg</td>
<td>29.4</td>
<td>49.0</td>
</tr>
<tr>
<td>Digestible fibre, g/kg feed</td>
<td>74.8</td>
<td>110 ***</td>
</tr>
<tr>
<td>Enteric CH₄, L/pig/d</td>
<td>3.1</td>
<td>4.6 ***</td>
</tr>
<tr>
<td>VS, g DM/pig/d</td>
<td>192</td>
<td>315 ***</td>
</tr>
<tr>
<td>B₃, L CH₄ / kg OM</td>
<td>377</td>
<td>376</td>
</tr>
<tr>
<td>CH₄ production, L/pig/d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage simul. (100 d, 30°C)</td>
<td>55</td>
<td>97 ***</td>
</tr>
<tr>
<td>MCF, %</td>
<td>71%</td>
<td>77%*</td>
</tr>
</tbody>
</table>

* soybean meal replaced by wheat DDGS and rapeseed meal

Jarret et al., 2011

Effect of type of diet and duration of storage on MCF (%) of slurry in mesophylic conditions

<table>
<thead>
<tr>
<th></th>
<th>Duration of anaerobic storage simulation, days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>High protein</td>
<td>1.3%</td>
</tr>
<tr>
<td>Low protein</td>
<td>4.6%</td>
</tr>
<tr>
<td>High fiber</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

IPCC : For liquid effluent and slurry without natural crust cover and warm temperature (>28 °C), the proposed MCFs are at 80% on average

Jarret et al., 2011
Effect of nutrition on nutrient flow in pig production

- Reduction of excretion of nitrogen
- Reduction of gaseous losses
- Effect of feeding on odors
  - Reduction of excretion of phosphorus
- Reduction of excretion of trace elements

Efficiency of P utilization in growing pigs

- Phosphorus intake [100]
- Phosphorus retention [30]
- Absorbed phosphorus
- Faecal phosphorus [55]
- Urinary phosphorus [15]
- Manure [70]
Feeding strategies to reduce P excretion in pig manure

- **Strategies**
  - Better adjustment of P supply to P requirement
    - Phase feeding
  - Improved P digestibility in diets fed to pigs
    - More digestible phosphates
    - Use of phatase

### Phosphorus feeding strategy and P excretion

<table>
<thead>
<tr>
<th></th>
<th>Corpen, 2003</th>
<th>Perspectives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
<td>Two-phase</td>
</tr>
<tr>
<td>P, g/kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestation</td>
<td>6.5</td>
<td>5.0</td>
</tr>
<tr>
<td>Lactation</td>
<td>6.5</td>
<td>6.0</td>
</tr>
<tr>
<td>Pre-starter</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Starter</td>
<td>6.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Grower</td>
<td>5.8</td>
<td>4.8</td>
</tr>
<tr>
<td>Finisher</td>
<td>5.8</td>
<td>4.4</td>
</tr>
<tr>
<td>Average</td>
<td>6.0</td>
<td>4.9</td>
</tr>
<tr>
<td>P per slaughter pig (115 kg)</td>
<td>1.91</td>
<td>1.54</td>
</tr>
<tr>
<td>Intake</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Retention</td>
<td>1.31</td>
<td>0.94</td>
</tr>
<tr>
<td>Excretion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% of standard</td>
<td>100</td>
<td>72</td>
</tr>
</tbody>
</table>
Evolution of average P excretion per kg pig produced in France

Effect of nutrition on nutrient flow in pig production

- Reduction of N excretion
- Reduction of gaseous losses
- Effect of feeding on odours
- Reduction of excretion of Phosphorus

✓ Reduction of excretion of trace elements
Estimates of Zn and Cu balance\(^1\) according to different scenarios (Former EU regulation, actual EU regulation and perspectives)

<table>
<thead>
<tr>
<th></th>
<th>Cu</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Former Actual Persp.</td>
<td>Former Actual “Actual” Persp.</td>
</tr>
<tr>
<td>Concentration (ppm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prestarter</td>
<td>175 170 10</td>
<td>250 150</td>
</tr>
<tr>
<td>starter 2</td>
<td>175 170 10</td>
<td>250 150</td>
</tr>
<tr>
<td>fattening pigs</td>
<td>120 25 10</td>
<td>250 150</td>
</tr>
<tr>
<td>sows</td>
<td>100 25 10</td>
<td>250 150</td>
</tr>
<tr>
<td>Balance (0-110 kg BW)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>intake (g/pig)</td>
<td>40.4 13.0 3.1</td>
<td>78.3 47.0 63.4</td>
</tr>
<tr>
<td>excreted (g/pig)</td>
<td>40.3 12.9 3.0</td>
<td>75.8 44.5 61.0</td>
</tr>
<tr>
<td>Slurry (mg/kg DM)</td>
<td>1060 348 80</td>
<td>1995 1171 1604</td>
</tr>
<tr>
<td>Delay, years</td>
<td>50 167 1040</td>
<td>99 175 125</td>
</tr>
</tbody>
</table>

\(^1\)calculated according to Jondreville et al. (2003), expressed per slaughter pig, including intake and excretion by sows.

\(^2\)delay to reach 50 mg Cu or 150 mg Zn/kg soil DM

\(^3\)in case of use of 2500 ppm of zinc in pre-starter diet as allowed in some EU countries

### Conclusion

- **Important improvements already achieved**
  - reduction of excretion of N, P, Cu and Zn
  - reduction of gaseous emissions
- **Nutrition is an efficient way to modify characteristics of manure**
  - pH
  - N compounds
for the future

- Reduction of excretion
  - Perspectives are more limited but still exists (trace elements > phosphorus > nitrogen)
- Manipulation of characteristics of excreta
  - May reduce emissions and odors
  - Possible antagonisms (CH₄ – NH₃)
  - Better adapt manure composition to treatment or crop requirements
- a more global approach is required
  - Optimization of (plant <-> animal <-> manure) system
  - Consider the environment impact associated to the production of the feed ingredients
  ⇒ Modelling - Life Cycle Assessment
Controlling odour on pig farms

Alison Holdsworth
Lead technical Adviser for Intensive Pig and Poultry farms
Environment Agency UK

Why is Odour an issue?

- Affects a person’s quality of life
- Complaints generate increased workloads
- Impacts on planning and development decisions
- Can become a Site of High Public Interest
The role of the regulator

In the UK, the competent authority responsible for regulating such sites is

- the Environment Agency (EA) if the site has a permit, and/or
- the Local Authority for ‘statutory nuisance’

The Odour permit condition

‘Emissions from the activities shall be free from odour at levels likely to cause pollution outside the site, as perceived by an authorised officer of the Environment Agency, unless the operator has used appropriate measures, including, but not limited to, those specified in any approved odour management plan, to prevent or where that is not practicable to minimise the odour’
Possible consequences for operators

- Enforcement action
- Revocation of permit
- Refusal of planning permission
- Refusal of permit expansion variations

Typical Odour Concentrations

ouE/m³ *

- Background 15 - 200
- Pig Buildings 1,000 - 20,000
- Poultry Buildings 500 - 2,000
- Sewage Inlet Works 500 - 25,000
- Sludge Tank Headspaces 15,000 - 2.5m
- Scrubber Air Outlets 300 - 10,000
- Biofilter Air Outlets 300 - 10,000

* (European Odour Units per Cubic metre)
Causes of odour emissions

May be due to
- Proximity – too close or upwind of neighbours
- Housing design
- Management; or
- a combination of the above

Possible sources of odour 1

Housing design
- Defined feeding, lying and dunging areas
- Feeders and drinkers sited to avoid spillages and cross contamination
- Temperature and humidity checks
Housing - slurry systems

- Slurry is removed frequently as possible and a void is always maintained beneath slats
- Slurry temperature is minimised
- Surface area of slurry is minimised
- Slurry and drainage channels are clear of deposits
- Manure is not allowed to collect above slats
Housing - solid manure systems

- Bedding material is kept dry during storage prior to use
- Sufficient bedding used to keep pigs clean and absorb excreta
- Ponding prevented on floors and drains are maintained
- Maintenance of scrapers, belts or slurry extraction sluices
- All scraped areas are maintained

Possible sources of odour 2

Management:

- Feed
- Manure / slurry handling
- Landspreading
- Carcasses
Management - feed

- Choice of feed – appropriate diets and reduced protein
- Clean up spillages
- Enclosed handling
- Timing of deliveries
- Treat any pests in feed
- Remove waste feed

Management - manure /slurry storage and land spreading

- Slurry stores covered
- Dirty water and storage tanks emptied regularly
- Land spreading:
  - Odorous manure on arable land incorporated within 24 hours
  - Slurry applied using low trajectory splash plate or boom, shallow or deep injector
  - Slurry applied to growing crops whenever possible or if not, un-cropped land to be cultivated within 12 hours of application
Management - carcasses

- Covered storage
- Storage away from sensitive receptors
- Carcasses disposed of promptly
- Incinerator licensed and well maintained
- Incinerator ash disposed of appropriately
- If not incinerated on site, carcasses disposed of legally, as frequently as possible

Investigating an odour complaint

- Using H4 Guidance:
  - Frequency of detection;
  - Intensity as perceived;
  - Duration of exposure;
  - Offensiveness;
  - Receptor sensitivity
- Sniff testing
- Consider other odour sources
- Wind Direction and Weather
- Upwind and downwind monitoring
Odour Monitoring

Nasal Ranger
**Scentroid SM100 Air Spectrum**

- Sample of ambient air drawn in and diluted with fresh odourless air from air tank.
- Valve controls the ratio of fresh to ambient air.
- Mixed air sent through hose to face mask.
- Operator slowly increases concentration of mix until the odour is detected.
- A scale on the valve shows the Dilution to Threshold ratio or odour intensity.

---

**Appropriate measures**

This will be informed by a combination of meeting:

- How to Comply – Intensive farming
- BRef (BAT reference document);
- H4 guidance;
- Sector specific guidance notes;
- Code of Practice including pig checklist; or
- other techniques used in the sector

All of the above to be addressed in the site’s Odour management plan.
Areas covered by the checklist

Odour can arise from many different parts of the production process, the following are the five key areas for consideration, the contribution of each will be site specific.

- Livestock
- Feed, storage, management, preparation and feeding
- Housing
- Manure and slurry storage and management
- Waste, skips and carcasses
What do operators need to do?

- Have an odour management plan if sensitive receptors are within 400m, or there is a history of complaints
- Operate at BAT
- Use and review all appropriate measures
- **Design** their farms to reduce emissions
- **Manage** their farms to reduce emissions
- Investigate – use checklist
- Keep an Odour diary

Things to consider

- End of pipe solutions – but scrubbers and biofilters are expensive and may not be viable
- Covering lagoons and slurry stores
- Feed composition and additives may be better ‘front end’ options
- Better site screening and layout of buildings
- Weather monitoring before carrying out specific operations
- Slurry additives and deodorisers
- Reduced stocking densities
Community Engagement

- Understand what the complaints/communities issues are
- How can these issues be addressed
- Understand when and how to interact
- Create and implement a written Community Engagement Plan
- Maintain the relationships

Predicting a problem - modelling may help

- **May be required** as part of a planning application
- Can be useful to demonstrate a mitigation technique
- Indicative exposure level criterion:
  - 3 ouEm$^3$ as a 98th percentile of hourly means
  - experience is that above this level, farm will get complaints
Guidance documents on the EA webpages

- Main Intensive farming web page
- How to Comply – Intensive farming
- BRef (BAT reference document);
- H4 odour guidance
- Odour guidance
- Code of Conduct

Any questions?
Cattle Housing Systems

- Majority naturally ventilated

**Dairy**
- Predominantly slurry
- Cubicle house - solid floor
- - slatted floor
- Deep litter system
- Tied stall

**Beef**
- Varies by country – e.g. UK predominantly FYM, Ireland predominantly slurry

**Outdoor yards**
Dairy cubicle house – solid floor
Dairy tie-stall house

Beef cattle – deep litter
Dairy cow collecting yard

Dairy cow exercise yard
Main environmental impacts

- **AIR**
  - Ammonia emissions: major source
  - GHG Emissions: minimal from slurry systems
    some from deep litter systems
  - NMVOCs: not well characterized

- **WATER**
  - Yards – only if not properly contained

**FOCUS ON AMMONIA**

Ammonia Emissions - Major influencing factors

- Emitting surface area
- Strength of emitting source
- Resistance to ammonia transfer
- Fouled surface area
- Dietary impacts
- Temperature
- Air flow
- Surface characteristics
Emission measurement

- Ferm tubes
- Tracer ratio techniques

Yards
- Equilibrium concentration technique

Typical ammonia emission factors

<table>
<thead>
<tr>
<th>Country</th>
<th>Dairy cow cubicle</th>
<th>Beef cattle deep litter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>17</td>
<td>12</td>
</tr>
<tr>
<td>Germany</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Netherlands</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>UK</td>
<td>31</td>
<td>23</td>
</tr>
<tr>
<td>Switzerland</td>
<td>17</td>
<td>37</td>
</tr>
</tbody>
</table>

(Reidy et al., 2008; 2009)

Dairy: 10-20 kg per animal place per year
Beef: 3.5 – 8.5 kg per animal place per year

Sommer et al. (2006):
Tie stalls: 6% TAN, cubicle houses: 12-17% TAN; deep litter: 12% TAN
Emission reduction methods

- Generally less development than for intensive pig and poultry housing systems

**Slurry systems:**
- Extended grazing
- Minimise fouled surface area
- Rapid removal of excreta to storage
- Rubber slat mats
- Urease inhibitors?

**Deep litter systems:**
- Extended grazing
- Minimise fouled surface area
- Additional, targeted bedding

**Mitigation examples – floor design and scraping**

- e.g. Swierstra et al. (2001)
- 35 – 46% reduction (with/without perforations)
- Welfare benefits
- Scraper operation essential
Mitigation examples – cleaning, urease inhibitor

Controlled yard studies:

<table>
<thead>
<tr>
<th>Control measure</th>
<th>% reduction (cf. scraping)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure washing + scraping</td>
<td>89</td>
</tr>
<tr>
<td>Urease inhibitor + scraping</td>
<td>61</td>
</tr>
<tr>
<td>Reduced yard area (by 50%)</td>
<td>44</td>
</tr>
</tbody>
</table>

On-farm assessment:

Misselbrook et al. (2006, AE)

Mitigation examples – slat mats

- To reduce lameness and slipping
- Reduce surface area of openings
- Claimed to reduce emissions
- Limited evidence – e.g. Ahrens et al. (2011, JDS) found no difference
Mitigation examples – additional bedding

- Gilhespy et al. (2009, BE)

Mitigation examples – bedding type

- Laboratory scale study (Misselbrook et al., 2005 JDS)
- Emission related to absorbance (positive) and bulk density (negative)
## Summary – EPMAN NH₃ Guidance Document

<table>
<thead>
<tr>
<th>Housing type</th>
<th>Reduction (%)</th>
<th>Emission (kg place⁻¹ yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubicle house (ref 1)</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Grooved floor (Cat. 1)</td>
<td>25</td>
<td>9.0</td>
</tr>
<tr>
<td>Optimal climatisation, roof insulation (Cat. 1)</td>
<td>20</td>
<td>9.6</td>
</tr>
<tr>
<td>Chemical air scrubbers (Cat. 2)</td>
<td>70-95</td>
<td>1.2</td>
</tr>
<tr>
<td>Sand bedding (Cat. 2)</td>
<td>60</td>
<td>4.8</td>
</tr>
<tr>
<td>Pine shavings bedding (Cat. 2)</td>
<td>30</td>
<td>8.4</td>
</tr>
<tr>
<td>Straw bedding (Cat. 2)</td>
<td>50</td>
<td>6.0</td>
</tr>
<tr>
<td>Extended grazing (Cat. 1)</td>
<td>20-80</td>
<td>2.5-9.6</td>
</tr>
</tbody>
</table>

NB: DRAFT document

## Questions?
Overview environmental impact of poultry

- Which Sustainability issues?
- Where do they occur?
- Laying Hens
- Broilers
Predominant systems in poultry

Broiler barn - Single tier barn - Aviary
### Planet: environmental issues (effect – causes)

- **Eutrophication**: loss of N & P
- **Decrease drink water quality**: leaching of NO₃⁻ (nitrate)
- **Public health (besides farmer & animal)**:
  - emissions of fine dust, micro organisms & odour
- **Acidification**: emissions of NH₃ (deposition)
- **Biodiversity = loss of species**:
  - use of gmo species,
  - use of agro-chemicals,
  - transfer nature to crops,
  - intensity of production,
  - land use!
- **Global warming**: emissions of CO₂, CH₄, N₂O,
- **Depletion of natural (limited) sources**:
  - use of phosphate, water, energy
- **Soil quality (among others organic matter)**:
  - management (input vs. output)

### Agricultural impact world-wide

- **Jason Clay, World Wildlife Fund (WWF)**
- On feeding the world, and global environmental issues related to mining, production & finally daily consumption
- [http://www.youtube.com/watch?v=jcp5vvxtEaU](http://www.youtube.com/watch?v=jcp5vvxtEaU)
- [http://www.youtube.com/watch?v=cI1G796NwWk](http://www.youtube.com/watch?v=cI1G796NwWk)
- Or search for Jason Clay on YouTube
  - Raise your awareness on global issues
  - Learn from the examples in general sense
Agricultural impact world-wide

- Jason Clay, World Wildlife Fund (WWF)
- Book: World Agriculture and the Environment
- [Link to book](http://books.google.nl/books?id=_RU8D9kB714C&printsec=frontcover&hl=nl#v=onepage&q&f=true)
- Contents
  - Introduction pages 1-10
  - Agricultural trends and realities, pages 11-43
  - Effects & impacts, pages 45-53
Ecological aspects of egg production systems, with special attention for organic

Dr. Sanne Dekker
André Aarnink, Imke de Boer, Peter Groot Koerkamp

Egg production system: system demarcation
What is organic egg production?

1) Limited use of external resources

- No artificial fertilizers
- No pesticides & herbicides
- No genetic modification: plants & amino acids
- Limited medication

2) Loose hen housing

- multi-tier or aviary
- traditionally: single tier barn

3) Access to an outdoor run

---

Egg products (production systems)

<table>
<thead>
<tr>
<th>Egg product</th>
<th>Housing</th>
<th>Outdoor run</th>
<th>External resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery cage</td>
<td>Battery cage</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>(code 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barn (code 2)</td>
<td>Single-tiered</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-tiered</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Free range (code 1)</td>
<td>Single-tiered</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Multi-tiered</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Organic (code 0)</td>
<td>Single-tiered</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Multi-tiered</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

1 In organic agriculture use of the following external resources is prohibited: artificial fertilizer, pesticides, herbicides, GMO’s and use of medication is limited.
Example aviary housing: Farm 1

Organic aviaries in experiment: Legend

- dimension (m)  | manure belt
- ground        | wired floor
- nestbox       | perch
- feed chain    | sampling point outside air
- feed caster   | sampling point inside air
- round feeder  | manure drying duct
- water nipple  | exhaust fan
- round drinker | pophole
- outdoor run   | inlet valve
- winter garden | transparent impermeable curtain
- solid wall / floor / roof | windbreak curtain
Results: N load (similar for P)

- Hens outside: 1.7 - 13%

- N fertilization standard: 170 kg ha\(^{-1}\) yr\(^{-1}\)

Environmental impact of broilers


- In general same pattern as for laying hens:
  - Feed responsible for 60-80% of impact
  - Manure & management very important
<table>
<thead>
<tr>
<th>Year</th>
<th>NH₃ emissions (g/year per broiler place)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985 (N-balance)</td>
<td>160</td>
</tr>
<tr>
<td>1986-1987 (first measurements)</td>
<td>50</td>
</tr>
<tr>
<td>1992-1994 (Spelderholt)</td>
<td>81</td>
</tr>
<tr>
<td>1997-1998 (practice; E5.100)</td>
<td>80</td>
</tr>
<tr>
<td>Low Emission Systems (RAV 1 October 2012)</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Litter drying (netting or perforated floor - E5.1/5.2) 5 / 14</td>
<td></td>
</tr>
<tr>
<td>Cages / tiers with wire floors (E5.3 - not allowed in EU) 5</td>
<td></td>
</tr>
<tr>
<td>Traditional system with chemical air scrubber (E5.4) 8</td>
<td></td>
</tr>
<tr>
<td>Traditional system + floor heating/cooling (E5.5) 45</td>
<td></td>
</tr>
<tr>
<td>Traditional system with biological air scrubber (E5.7) 24</td>
<td></td>
</tr>
<tr>
<td>Trad. system with drying of litter (E5.6, 5.11, 5.14) 35-37</td>
<td></td>
</tr>
<tr>
<td>Multiple tiers with litter on belt (Patio: E5.9) 18-40</td>
<td></td>
</tr>
</tbody>
</table>

**Litter drying: internal ventilation & floor heating (ImagO)**
Increase NH₃ emissions broilers: explanation

- drinking nipples
- climate control
- water restriction
- litter type & layer depth

Emission of NH₃ (g NH₃ yr⁻¹ per hen place)

RAV: official listed emission factors for permits
### Some literature

<table>
<thead>
<tr>
<th>Year</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>Voorburg / Monteny</td>
<td>Acidification research in the Netherlands: emissions of NH3</td>
</tr>
<tr>
<td>1994</td>
<td>Groot Koerkamp et al.</td>
<td>Review on Emissions of Ammonia from Housing Systems for Laying Hens in Relation to Sources, Processes, Building Design and Manure Handling (JAER)</td>
</tr>
<tr>
<td>1998</td>
<td>Groot Koerkamp et al.</td>
<td>Concentrations and emissions of ammonia in livestock buildings in Northern Europe (JAER)</td>
</tr>
<tr>
<td>2004</td>
<td>Lacey/Mukhtar/Carey</td>
<td>A review of literature concerning odors, ammonia, and dust from broiler production facilities: 1-3, 4. Remedial management practices (JAPR)</td>
</tr>
<tr>
<td>2004</td>
<td>Ritz/Fairchaild/Lacey</td>
<td>Implications of Ammonia Production and Emissions from Commercial Poultry Facilities: A Review (JAPR)</td>
</tr>
<tr>
<td>2004</td>
<td>Rotz</td>
<td>Management to reduce nitrogen losses in animal production (JAS) !</td>
</tr>
<tr>
<td>2008</td>
<td>Faulkner/Shaw</td>
<td>Review of ammonia emission factors for United States animal agriculture (Atmospheric Environment)</td>
</tr>
</tbody>
</table>
Greenhouse gas emissions from poultry

- Methane: results from anaerobic processes in manure
  - E.g. slurry, wet litter

- Nitrous Oxide:
  1. Aerobic nitrification: \( \text{NH}_4^+ \rightarrow \text{NO}_3^- \)
  2. Anaerobic denitrification: \( \text{NO}_3^- \rightarrow \text{N}_2 \)
  - Results from incomplete denitrification in manure
  - E.g. belt manure, friable litter (changing conditions)
Current emission factors

- List of all housing systems (Rav for ammonia)
  - Emission factors for ammonia, odour & dust
  - Used for legislative permits of farmers
- NIR emission factors for green house gases
  - Based on Tier 2 calculation (CH₄)
  - IPCC defaults (N₂O: 0.01% / 2%)
- Goal:
  - Update of emission factors of traditional systems
  - Emission factors for low emitting systems
  - Emission factors for greenhouse gases

Measurements in practice: strategy

- Measurement program 2008-2011
- Animal – housing types:
  - ✔ Broiler breeders: traditional single tier with storage
  - ✔ Broilers: traditional floor systems
  - ✔ Rearing laying hens: -
  - ✔ Laying hens:
    - Single tier traditional loose housing with storage
    - Multi tier aviary with belts – no manure drying
Measurements in practice: strategy

- Replicates: 2 or 4 commercial houses
- 6 days of 24 hours (means) per replicate (validated and based on strategy for ammonia emission)
- Ventilation rate: fans or CO₂ balance method
- Gas concentrations of NH₃, PM, odour, CH₄, N₂O: acid traps, cyclones, olfactometry, GC-MS

References & sources of hard work


Groenestein, Sluis en Mosquera, 2012. Journal of Integrative Environmental Sciences (Submitted)
ingoing air

exhaust air

PM2,5 cycloon

PM10 cycloon

Condens filter and 'constant flow pump'
## Results

### New emission factors

<table>
<thead>
<tr>
<th>Type (-)</th>
<th>Age (wks)</th>
<th>Description system (-)</th>
<th>ME (kg/a.bird)</th>
<th>NIR (kg/a.bird)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent stock</td>
<td>&gt;19</td>
<td>Cages, single &amp; multi-tier aviary, traditional *</td>
<td>0.082</td>
<td>0.029</td>
</tr>
<tr>
<td>Broilers</td>
<td>0-6</td>
<td>Traditional *, litter drying, Patio</td>
<td>0.004</td>
<td>0.019</td>
</tr>
<tr>
<td>Rearing Hens</td>
<td>&lt;18</td>
<td>Cages &amp; aviaries with belts</td>
<td>0.013</td>
<td>0.009</td>
</tr>
<tr>
<td>Laying Hens</td>
<td>&gt;18</td>
<td>Cages, slurry</td>
<td>0.671</td>
<td>0.436</td>
</tr>
<tr>
<td>Laying Hens</td>
<td>&gt;18</td>
<td>Cages &amp; aviaries * with belts, traditional loose housing *</td>
<td>0.034</td>
<td>0.022</td>
</tr>
</tbody>
</table>

*ME: measured */derived**  **NIR: national inventory report
Summary

- Methane: generally ME > NIR
  - Parent stock broiler: + 183%
  - Broilers: - 79%
  - Rearing hens: + 44%
  - Laying hens: + 55%

New emission factors for Nitrous Oxide

<table>
<thead>
<tr>
<th>Type</th>
<th>Age (wks)</th>
<th>Description system (-)</th>
<th>ME (kg/a.bird)</th>
<th>NIR (kg/a.bird)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent stock</td>
<td>&gt;19</td>
<td>Cages, single &amp; multi-tier aviary, traditional *</td>
<td>0.038</td>
<td>0.040</td>
</tr>
<tr>
<td>Broilers</td>
<td>0-6</td>
<td>Traditional *, litter drying, Patio,</td>
<td>0.011</td>
<td>0.020</td>
</tr>
<tr>
<td>Rearing Hens</td>
<td>&lt;18</td>
<td>Cages &amp; aviaries with belts</td>
<td>0.006 (0.0058)</td>
<td>0.010</td>
</tr>
<tr>
<td>Laying Hens</td>
<td>&gt;18</td>
<td>Cages, slurry or belts without drying</td>
<td>0.0007</td>
<td>0.001</td>
</tr>
<tr>
<td>Laying Hens</td>
<td>&gt;18</td>
<td>Cages &amp; aviaries * with belts, traditional loose housing *</td>
<td>0.014 (0.0136)</td>
<td>0.020</td>
</tr>
</tbody>
</table>

ME: measured */derived  NIR: national inventory report
Summary

- **Methane:** generally ME > NIR
  - Parent stock broiler: +183%
  - Broilers: -79%
  - Rearing hens: +44%
  - Laying hens: +55%

- **Nitrous oxide:** generally ME < NIR
  - Parent stock broiler: -5%
  - Broilers: -45%
  - Rearing hens: -40%
  - Laying hens: -30%

- Methane & nitrous oxide: no effect of scrubbers

Summary

- **Methane**
  - Substantial variation between farms
  - Broilers: increase during whole growing period
  - Laying hens, for barn & aviary: decrease to constant level

- **Nitrous oxide**
  - Substantial variation between farms
  - Broilers: increase during whole period
  - Laying hens, for barn & aviary: no trend
Impact of new emission factors on total GHG emission from livestock for the Netherlands

Conclusions

- Measurements differ substantially from NIR factors:
  - Emission factors methane: ME > NIR
  - Emission factors nitrous oxide: ME < NIR
- Variation
  - Time & space: repetitions & replicates necessary
- Mitigation
  - No slurry – no anaerobic conditions
  - Manure & slurry: drying limits biological activity
  - System change, including storage?
- Impact of poultry on total GHG emissions from livestock: Rather limited
Dust in animal houses: Sources, effects and control

Albert Winkel MSc, Wageningen Livestock Research
Two results of shooting a photo inside a pig or poultry house, using a flash...

- Definition: ‘Particulate Matter’ (PM) > aerial (floating) matter as small particles or droplets
- Classification of PM according to the max. aerodynamic diameter of the particles (µm), denoted as the number behind ‘PM’:

<table>
<thead>
<tr>
<th>Name</th>
<th>Fraction</th>
<th>Definition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total dust</td>
<td>PM100</td>
<td>All particles surrounded by air in a given volume of air</td>
<td>ISO 7708:1995</td>
</tr>
<tr>
<td>Inhalable</td>
<td>PM100</td>
<td>Mass fraction of total airborne particles which is inhaled through the nose and mouth</td>
<td>NEN-EN 481:1993</td>
</tr>
<tr>
<td>Fine dust</td>
<td>PM10</td>
<td>Particulate matter which passes through a size-selective inlet with a 0.1 µm efficiency cut-off at 1 µm aerodynamic diameter</td>
<td>NEN-EN 12341:1998</td>
</tr>
<tr>
<td>Thoracic</td>
<td>PM10</td>
<td>Mass fraction of total airborne particles which penetrate beyond the larynx</td>
<td>ISO 7708:1995</td>
</tr>
<tr>
<td>Respirable</td>
<td>PM4</td>
<td>Mass fraction of inhaled particles which penetrate to the unciliated airways</td>
<td>ISO 7708:1995</td>
</tr>
<tr>
<td>Very fine dust</td>
<td>PM2.5</td>
<td>Particulate matter which passes through a size-selective inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter</td>
<td>NEN-EN 14907:2005</td>
</tr>
</tbody>
</table>
- Dust concentrations are being expressed as:
  - mg/m³ (mass concentration), or;
  - number/m³ (particle concentration)

- Literature into sources of dust in animal houses:

<table>
<thead>
<tr>
<th>Animal</th>
<th>Main sources</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layers (cage)</td>
<td>Skin flakes, feed, feathers</td>
<td>Koon et al., 1963</td>
</tr>
<tr>
<td></td>
<td>Feed (80–90%), animal (4–12%), faeces (2–8%)</td>
<td>Man et al., 1971</td>
</tr>
<tr>
<td>Layers (non-cage)</td>
<td>Litter (55–68%), animal (2–12%), faeces (2–8%)</td>
<td>Man et al., 1971</td>
</tr>
<tr>
<td>Broilers</td>
<td>Down feathers (&gt;10%), uric acid crystals (&gt;10%), feed (&lt;1%), microorganisms (&lt;1%), no faeces</td>
<td>Aarnink et al., 1999</td>
</tr>
<tr>
<td>Pigs (sows, piglets, G-F pigs)</td>
<td>Feed, faeces (bacteria, epithelial cells), skin and hair flakes, fungi, seeds and grain particles, insect parts, mineral ash particles</td>
<td>Donham et al., 1986</td>
</tr>
<tr>
<td></td>
<td>Feed (starch particles, grain particles), skin flakes</td>
<td>Heber et al., 1988</td>
</tr>
<tr>
<td></td>
<td>Feed (&gt;10%), skin flakes (&gt;10%), faeces (1–3%), uric acid crystals (1–3%), no microorganisms</td>
<td>Aarnink et al., 1999</td>
</tr>
</tbody>
</table>

- Recent study:


- Dust in animal houses very heterogeneous in size, shape and density
- Particles hard to trace back to sources based on morphology
Source contributions (%) to 2.5-10 µm fraction:

<table>
<thead>
<tr>
<th>Source</th>
<th>Layers</th>
<th>Broilers</th>
<th>Turkeys</th>
<th>Sows</th>
<th>G-F Pigs</th>
<th>Cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faeces</td>
<td>87.7</td>
<td>82.8</td>
<td>35.8</td>
<td>85.4</td>
<td>84.5</td>
<td>17.7</td>
</tr>
<tr>
<td>Feathers</td>
<td>10.2</td>
<td>17.2</td>
<td>31.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Skin</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.6</td>
<td>11.3</td>
<td>-</td>
</tr>
<tr>
<td>Feed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.2</td>
<td>24.4</td>
<td>-</td>
</tr>
<tr>
<td>Litter</td>
<td>-</td>
<td>-</td>
<td>32.5</td>
<td>-</td>
<td>-</td>
<td>22.1</td>
</tr>
<tr>
<td>Straw</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.1</td>
</tr>
<tr>
<td>Silage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.6</td>
</tr>
<tr>
<td>Outside</td>
<td>2.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>13.2</td>
</tr>
</tbody>
</table>


Physical properties of PM in animal houses:

- The mass of PM in animal houses is mainly determined by the larger particles (>6 µm)
- According the mass concentration (mg/m³), PM2.5 particles account for only 5-8% of the total mass of PM10 (exception for turkeys: approx. 45%)
- According the number of particles (#/m³), PM2.5 particles account for >95% of the total number of particles <10 µm
- Ergo: mass and particle concentrations give opposite picture
Studies scars; effects reported:
- Trachea en air sack lesions in turkeys (Anderson et al., 1968)
- Statistical relationship between dust concentration and mortality in layers (Guarino et al., 1999)
- Lower growth, higher mortality in broilers (Al Homidan et al., 2003)
- Lower feed intake and growth, Atrophic Rhinitis, Pneumonia/Pleuritis in pigs (Wathes et al., 2002; Murphy & Cargill, 2004; Hamilton et al., 1999)

Epidemiological studies show higher risks to:
- ODTS: organic dust toxic syndrome; flu-like condition directly after exposure
- COPD: chronic obstructive pulmonary disease; chronic bronchitis and lung emphysema
- Asthma: chronic irritation / inflammation of lower respiratory tract
- General: decreased lung function of pig and poultry farmers as compared to reference population, more respiratory complaints (coughing, sneezing, wheezing, ...)

Harmful effect of dust for workers/animals depends on:
- intensity of the labour (depth of respiration)
- personal sensitivity (heredity, smoking, etcetera)
- duration of exposure (longer for pig farmers)
- origin and character of the dust (e.g. endotoxins)
- dust concentration (peaks during labour activities)
- diameter (small particles penetrate deeper in lungs)

Animal emissions contribute to background PM

RIVM (Nat. Inst. for Public Health and the Env.; Buringh & Opperhuizen, 2002): Premature deaths:
- 1,700-3,000 People (short term) per year
- 10,000-15,000 People (long term) per year;

Studies on health of neighbouring residents scars but suggest some risk (e.g. Von Essen et al, 2005; Radon et al., 2007)

PM may function as a vector for:
- Odour and ammonia adsorbed to particles
- Allergens, Endotoxins & Pathogens
- Antibiotic residues
Effects of PM on neighbouring residents

- Air Quality Directive 2008/50/EC of May 21, 2008, Appendix XI: PM10 limit values for the ambient air:
  - day average PM10: 50 µg/m³ (0.050 mg/m³); with max. of 35 crossings per year (currently: 50-60)
  - year average PM10: 40 µg/m³ (0.040 mg/m³)
  - year average PM2.5: 25 µg/m³ (0.025 mg/m³)
- NL cannot comply with these limit values yet
- Animal houses (poultry & pigs) responsible for 20% of the total primary PM emission in NL
- Emission reduction measures necessary to comply

1. Design of low-dust housing concepts
2. Measures inside existing housings:
   a. Reducing sources of dust
   b. Reducing dust generation from sources
   c. Removal of dust that is already generated
   d. Prevent particles to become airborne
   e. Removal of particles from air inside house
   f. Reduce chance of / prevent inhalation
3. ‘End of pipe measures’:
   g. Use of respirator masks
   h. Removal of particles at exhaust

Source
Exhaust
1. Negative air ionization in broilers
   a. Finished
   b. Not successful
2. Oil film on litter of broilers
   a. Finished
   b. Validation at farms
3. Water film on litter of layers
   Not successful
4. Simple water scrubber (end of pipe)
   Validation at farms
5. Chemical scrubber or bioscrubber (e.o.p.)
   Finished
6. Dry filter wall = impaction curtain (e.o.p.)
   Finished
7. Biofilter (e.o.p.)
   Validation at farms
8. Electrostatic Precipitator (e.o.p.)
   Validation at farms
9. Heat exchanger (e.o.p.)
   Validation at farms
10. Terra Sea broiler housing (e.o.p.)
    Validation at farms
11. Manure drying systems (e.o.p.)
    Validation at farms
12. Recirculation with ionization removal
    Validation at farms
End of pipe technique: air scrubbers

Treatment of exhaust air necessary in high density areas

- NL: since 1990’s development of mitigation options in animal production:
  - Manure storage and application techniques
  - Housing systems, including air scrubbers
- Today, ever more stringent emission standards for existing and new facilities require substantial emission reductions for ammonia, odour and particulate matter (PM10 and PM2.5)
  ⇒ End-of-pipe air treatment is essential to comply with these standards (at least on the short term)
Air scrubber...

Acid scrubber: chemical process

- **Dissolution:**
  \[
  \text{NH}_3 \ (g) \rightarrow \text{NH}_3 \ (aq) \rightarrow \text{NH}_4^+ \ (aq) + \text{OH}^- \ (aq)
  \]

  Dosing of sulphuric acid (pH = 2 - 4) drives equilibrium to right side

- **Net reaction:**
  \[
  2 \text{NH}_3 \ (g) + \text{H}_2\text{SO}_4 \rightarrow 2 \text{NH}_4^+ (aq) + \text{SO}_4^{2-} \ (aq)
  \]

  Ammonium sulphate solution is discharged from system (~30 g N/L)

  Odour removal: little or none
Bioscrubber: bacterial conversions

- Nitrification (pH = 6.5 - 7.5):
  \[ \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^- \quad \text{Dissociation / Dissolution} \]
  \[ \downarrow 1.5 \text{O}_2 \quad \text{Nitrosomonas Sp.} \]
  \[ \text{NO}_2^- + \text{H}^+ + 2 \text{H}_2\text{O} \]
  \[ \downarrow 0.5 \text{O}_2 \quad \text{Nitrobacter Sp.} \]
  \[ \text{NO}_3^- + \text{H}^+ + 2 \text{H}_2\text{O} \]

- Ammonium nitrite/nitrate solution is discharged (3 g N/L)
- Odour removal:
  - mixture of many compounds
  - oxidation to CO\textsubscript{2}, H\textsubscript{2}O and ‘by-products’

<table>
<thead>
<tr>
<th>Acid scrubber</th>
<th>Bioscrubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td></td>
</tr>
<tr>
<td>higher NH\textsubscript{3} removal (to 95%)</td>
<td>lower NH\textsubscript{3} removal (70%)</td>
</tr>
<tr>
<td>lower odor removal (30%)</td>
<td>higher odor removal (45%)</td>
</tr>
<tr>
<td>Wastewater</td>
<td></td>
</tr>
<tr>
<td>low volume</td>
<td>high volume (^{\text{(*)}})</td>
</tr>
<tr>
<td>acidic (^{\text{(*)}})</td>
<td>pH neutral</td>
</tr>
<tr>
<td>high nitrogen content</td>
<td>low nitrogen content</td>
</tr>
<tr>
<td>Process control</td>
<td></td>
</tr>
<tr>
<td>robust pH control</td>
<td>vulnerable to inhibition and low temp.</td>
</tr>
<tr>
<td>immediately operative</td>
<td>start-up several weeks</td>
</tr>
<tr>
<td>risk of clogging</td>
<td>risk of clogging</td>
</tr>
</tbody>
</table>

\(^{\text{(*)}}\) Denitrification and subsequent reuse of discharge water in the scrubber is not allowed in the Netherlands
\(^{\text{(*)}}\) In some cases acid addition is halted prior to discharge, resulting in neutral pH.
Example of a scrubber for application in poultry industry (2 wall design)
Air scrubbers in livestock industry (1/2)

- Both chemical and biological scrubbers are applied since ~1995 in NL, D and DK: mainly for ammonia abatement
- Commercially available as of-the-shelf product, ~10 manufacturers in the Netherlands
- Estimated scrubber use in NL (2008), pigs only:
  - Acids scrubbers: 64 million m³/hour (n>1000)
  - Biotrickling filters: 14 million m³/hour (n>100)
  - In total: nationwide 10 – 15 % of all piggery air is treated

Air scrubbers in livestock industry (2/2)

- Mainly applied in pig production, no poultry (coarse dust clogs filter packing)
- Biological and chemical scrubbers are now introduced again in poultry industry because of their PM10 removal capacity
Emission reduction as compared to traditional housing systems

- **NH₃:**
  - biological: 70%
  - chemical: 90%, 95%
  - combi: 70%, 85%, 90%

- **Odour:**
  - biological: 45%
  - chemical: 30%
  - combi: 70%, 75%, 80%, 85%

- **Fine dust (PM10):**
  - biological: 60%, 75%
  - chemical: 35%
  - combi: 80%
Conventional biofilter out of date! (?)

Regulations: housing systems and emissions

- National list of housing systems with emission factors for:
  - Ammonia, kg NH₃/animal/year, since 1995
  - Odour (OUE/animal/s), since 2006
  - Fine dust (g PM10/animal/year), since 2008
- Factors for all housing systems, in all animal categories
- Description of essential system elements in 'leaflets'
- Including end-of-pipe techniques: air scrubbers
- See: [www.infomil.nl](http://www.infomil.nl) - landbouw tuinbouw
Example leaflet biotrickling filter, 1998

Air scrubber leaflet / system description

- Description of working principle and set-up
- Schematic diagram / drawing
- Design parameters:
  - Brand/type of packing and demister + spec. surface area (m²/m³)
  - Packing width (cm)
  - Flow configuration: cross- or counter-current
- Operational parameters:
  - Maximum air loading rate (m³/m²/h or m³/m³/h)
  - EC (mS/cm) and pH bandwidth
  - Discharge water production (m³/y)
- Animal category and emission factors
Emissions of NH$_3$, N$_2$O and CH$_4$ from pig houses:
Influencing factors and mitigation techniques

François-Xavier PHILIPPE, Baudouin NICKS
Department of Animal Productions, Faculty of Veterinary Medicine, University of Liège, Belgium

Influencing factors at pig house level

- Climatic conditions
  - Ambient temperature
  - Ventilation: Rate, type, location of the fans
  - Bioclimatic comfort of the pigs
  - Effect on pig behaviour
**Influencing factors at pig house level**

- **Climatic conditions**
  - Ambient temperature
  - Ventilation: Rate, type, location of the fans
  - Bioclimatic comfort of the pigs
  - Effect on pig behaviour

- **Floor type and manure management**
  - Slatted floor systems
  - Bedded floor systems

---

**Influencing factors**

- **Floor type and manure management**
  - *Slatted floor systems*
    - Slat characteristics
      - Material characteristics

  ![Graph](image.png)

  Ammonia emission (concrete slats = 100)

  - Concrete slats
  - Plastic slats
  - Cast iron slats

  (Pedersen et al., 2008)
**Influencing factors**

- Floor type and manure management
  - *Slatted floor systems*
    - Slat characteristics
      - Slat profile

![Graph showing ammonia emissions](image)

(Hamelin et al., 2010)

**Influencing factors**

- Floor type and manure management
  - *Slatted floor systems*
    - Slat characteristics
      - Opening size

![Graph showing cumulative ammonia emissions](image)

(Svennerstedt, 1999)
Influencing factors

- Floor type and manure management
  - Slatted floor systems
    - Slat characteristics
      - Opening size

<table>
<thead>
<tr>
<th></th>
<th>Room 1</th>
<th>Room 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening size</td>
<td>15%</td>
<td>9%</td>
</tr>
<tr>
<td>Emissions (g/day.sow)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td>12.8</td>
<td>15.8</td>
</tr>
<tr>
<td>N₂O</td>
<td>0.47</td>
<td>0.52</td>
</tr>
<tr>
<td>CH₄</td>
<td>10.2</td>
<td>11.9</td>
</tr>
</tbody>
</table>

(Philippe et al., 2011)

Influencing factors

- Floor type and manure management
  - Slatted floor systems
    - Slurry emitting surface
      - Partly slatted floor system

<table>
<thead>
<tr>
<th></th>
<th>Slatted area</th>
<th>Slatted area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
<td>37%</td>
</tr>
<tr>
<td>NH₃ (g/day.pig)</td>
<td>16.1</td>
<td>9.7</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>25%</td>
</tr>
<tr>
<td>NH₃ (g/day.pig)</td>
<td>6.4</td>
<td>5.7</td>
</tr>
</tbody>
</table>

(Sun et al., 2008)

(Aarnink et al., 1996)
**Influencing factors**

- Floor type and manure management
  - *Slatted floor systems*
    - Slurry emitting surface
      - Partly slatted floor system

<table>
<thead>
<tr>
<th>Emissions (g/day.pig)</th>
<th>Room 1</th>
<th>Room 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃</td>
<td>5.57</td>
<td>5.75</td>
</tr>
<tr>
<td>N₂O</td>
<td>0.18</td>
<td>0.21</td>
</tr>
<tr>
<td>CH₄</td>
<td>4.64</td>
<td>4.77</td>
</tr>
</tbody>
</table>

(Philippe et al., 2012)

---

**Influencing factors**

- Floor type and manure management
  - *Slatted floor systems*
    - Slurry emitting surface
      - Partly slatted floor system

<table>
<thead>
<tr>
<th>Slatted area</th>
<th>100%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ (g/day.pig)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Winter</td>
<td>10.1</td>
<td>10.6</td>
</tr>
<tr>
<td>- Summer</td>
<td>7.7</td>
<td>13.6</td>
</tr>
</tbody>
</table>

(Guingand and Granier, 2001)

---

BATFarm European Workshop - Rennes, France, 19-20 March 2013
Influencing factors

Floor type and manure management

Slatted floor systems

- Slurry emitting surface
  - Partly slatted floor system

Reduction of emissions provided the soiling of the solid floor is prevented

Pit designs:
- Sloped pit walls
- Manure gutters

<table>
<thead>
<tr>
<th>Pit surface</th>
<th>NH$_3$ emissions</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglets</td>
<td>-67%</td>
<td>-35% Sloped wall</td>
</tr>
<tr>
<td>Fattening pigs</td>
<td>-28%</td>
<td>-28% Manure gutter</td>
</tr>
<tr>
<td>Gestating sows</td>
<td>-64%</td>
<td>-43% Manure gutter</td>
</tr>
</tbody>
</table>

(Van Zeeland and den Brok, 1998; Steenvoorden et al., 1999; Doorne et al., 2002)
**Influencing factors**

- **Floor type and manure management**

  **Slatted floor systems**

  - Slurry removal strategy
    - Frequent manure removal

<table>
<thead>
<tr>
<th>Removal frequency</th>
<th>Effects compared to deep-pit system</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 X/2 week</td>
<td>NH$_3$: -20%</td>
<td>Guingand, 2000</td>
</tr>
<tr>
<td>1 X/week</td>
<td>NH$_3$, CH$_4$, N$_2$O: -10%</td>
<td>Osada et al., 1998</td>
</tr>
<tr>
<td>1 X/week</td>
<td>NH$_3$: -38%, CH$_4$: -19%, N$_2$O: X2</td>
<td>Guarino et al., 2003</td>
</tr>
</tbody>
</table>

  Provided lower outside temperature than inside or specific manure storage conditions/treatments

**Influencing factors**

- **Floor type and manure management**

  **Slatted floor systems**

  - Slurry removal strategy
    - Pit flushing

  (Lim et al., 2004; Sommer et al., 2004)
Influencing factors

- Floor type and manure management

  *Slatted floor systems*

  - Slurry removal strategy
    - Pit flushing (6X/day)

  - Scraping

  Ineffective to reduce emissions
  Faeces and urine spreading over the pit

(Lagadec et al., 2012; Predicalo et al., 2007; Kim et al., 2008; Lagadec et al., 2012)
Influencing factors

- Floor type and manure management
  - *Slatted floor systems*
    - Slurry removal strategy
      - Scraping
      - Separation of urine from faeces
      - Significant reduction of emissions
        - NH$_3$ : 40-50%
        - N$_2$O : 40%
        - CH$_4$ : 20%
      - Facilitation of manure handling

References:

- Godbout et al., 2006; Lagadec et al., 2012

---

Influencing factors

- Floor type and manure management
  - *Bedded floor systems*
    - Bedded systems vs. Slatted floor systems

<table>
<thead>
<tr>
<th>Reference</th>
<th>NH$_3$</th>
<th>CH$_4$</th>
<th>N$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kermaarre and Robin (2002)</td>
<td>↓</td>
<td>-</td>
<td>↑</td>
</tr>
<tr>
<td>Kim et al. (2008)</td>
<td>↓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Philippe et al. (2011)</td>
<td>↓</td>
<td>Θ</td>
<td>↑</td>
</tr>
<tr>
<td>Kavolelis (2006)</td>
<td>Θ</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Balsdon et al. (2000)</td>
<td>↓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Philippe et al. (2007a)</td>
<td>Θ</td>
<td>Θ</td>
<td>Θ</td>
</tr>
<tr>
<td>Cabaraux et al. (2009)</td>
<td>↑</td>
<td>-</td>
<td>Θ</td>
</tr>
</tbody>
</table>

References:

- Godbout et al., 2006; Lagadec et al., 2012
Influencing factors

- Floor type and manure management
  - Bedded floor systems
    - Wide range of rearing techniques
      - Type of substrate: straw, sawdust, woodshaving, ...
      - Amount of substrate
      - Space allowance
      - Litter management

- Impact on physico-chemical properties of the litter

---

Influencing factors

- Floor type and manure management
  - Bedded floor systems
    - Type of substrate: Sawdust vs. Straw
    - with sawdust ...

<table>
<thead>
<tr>
<th>Reference</th>
<th>NH₃</th>
<th>CH₄</th>
<th>N₂O</th>
<th>CO₂-Eq</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nicks et al. (2003)</td>
<td>-62%</td>
<td>-51%</td>
<td>▲▲▲▲</td>
<td>×3</td>
</tr>
<tr>
<td>Nicks et al. (2004)</td>
<td>11%</td>
<td>33%</td>
<td>▲▲▲▲</td>
<td>×4</td>
</tr>
<tr>
<td>Cabaraux et al. (2009)</td>
<td>10%</td>
<td>30%</td>
<td>▲▲▲▲</td>
<td>×4</td>
</tr>
</tbody>
</table>
**Influencing factors**

- **Floor type and manure management**
  - *Bedded floor systems*
    - Amount of substrate
      - Low: 0.5 kg/day.pig
      - High: 1.0 kg/day.pig

![Bar chart showing NH3, N2O, and CH4 emissions for different amounts of substrate.](chart1)

**Influencing factors**

- **Floor type and manure management**
  - *Bedded floor systems*
    - Litter management – Supply strategy
      - Broadcast / Targeted straw application

![Graph showing ammonia emissions vs. straw application.](chart2)

*(Gilhespy et al., 2009)*
**Influencing factors**

- Floor type and manure management
  
  *Bedded floor systems*

  - Litter management – Supply strategy

  Broadcast / Targeted straw application

  ![Ammonia emissions graph](Gilhespy et al., 2009)

---

**Influencing factors**

- Floor type and manure management
  
  *Bedded floor systems*

  - Litter management – Removal strategy

  Frequent manure removal – Straw flow system

---

BATFarm European Workshop - Rennes, France, 19-20 March 2013
**Influencing factors**

- Floor type and manure management
  - **Bedded floor systems**
    - Litter management – Removal strategy

Frequent manure removal – Straw flow system

(Philippe et al., 2007 and 2012)
Conclusion

- Numerous techniques to reduce emissions, whatever the floor type

**BUT** contradictions depending on the circumstances and the gas

- Bedded floor: Large range of rearing systems → Environment inside the litter
  - Sawdust: NH₃, CH₄, N₂O
  - Increasing straw supply: NH₃, N₂O, CH₄
- Partly slatted floor: Provided prevention of soiled solid floor
- Frequent manure removal: Provided lower outside temperature or treatment
  + Solid/liquid separation: opportunity for further reductions

- Complete evaluation of the manure management process

Thank you for your attention
Best Available Techniques in five key environmental issues

According to the Comparison Programme on Permitting and Inspection of IPPC Pig Farming Installations in IMPEL Member Countries

Content

• Setting environmental permit conditions
• Inputs and influences in permit conditions
• Which BAT to be used
• The five key environmental issues
  – Description;
  – Problems found in setting environmental permits;
  – Recommendations made by IMPEL
Basic obligations to achieve a permit

In order to receive a permit an industrial or agricultural installation must comply with certain basic obligations. In particular, it must:

• prevent, recycle or dispose of waste in the least polluting possible way;
• prevent all large-scale pollution;
• use energy efficiently;
• ensure accident prevention and damage limitation;
• In addition, the decision to issue a permit must contain a number of specific requirements, concerning emission limit values for polluting substances, soil, water and air protection measures, release monitoring and:
• use all appropriate pollution-prevention measures, namely the best available techniques (which produce the least waste, use less hazardous substances, enable the substances generated to be recovered and recycled, etc.).
Are operators obliged to use all BAT’s?

• The permit conditions including ELVs must be based on the BAT, as defined in the IPPC Directive. BAT conclusions (documents containing information on the emission levels associated with the best available techniques) shall be the reference for setting permit conditions (IED Directive)

≠

• Use all appropriate pollution-prevention measures, namely the best available techniques (which produce the least waste, use less hazardous substances, enable the substances generated to be recovered and recycled, etc.) (Directive 2008/1/EC mandatory environmental conditions)
Permitting Authorities also have to take into account

- Social Issues
- Geographical areas
- Political boundaries
- Associated activities
- Interference by other authorities

Leading to **BATFARM** project

A scientific way to determine specific emissions based on field monitoring under different meteorological, social, cultural realities and using different equipment

Gives technical support to the permitting process
How permits are issued in MC

- Environmental Authorities
- Agricultural and Veterinary Authorities
- At a national or regional level

Conditioned by

- Ministries of agriculture – Responsible for regulations and manure spreading, aspects on animal housing;
- Veterinary Authorities – Animal health and welfare;
- Local authorities – responsible for local community interests and planning controls;
- Nature conservation bodies;
- Safety authorities
- Trade authorities

After this process can permits be the same in all MC?

- They might have the same structure
- Differences in MC were identified by IMPEL
- Recommendations made in Comparison Programme on permitting and Inspection of IPPC Pig Farming Installations in IMPEL Member Countries
Key environmental issues highlighted by MC in the Comparison Programme

1. Manure Storage;
2. Manure spreading on land;
3. Animal housing systems;
4. Air abatement techniques;
5. Odour assessment.

Manure storage’s risks

- Potential sources of emissions to air (ammonia, GHG and odour);
- Risk of pollution to water;
- Risk of explosions (safety issues)
Problems concerning permit setting conditions for manure storage

- Requirements concerning storage capacity;
- Materials for storage facilities;
- Covering of storage facilities;
- Specific conditions for coverage of lagoons;
- Prevention of leakage and protection of water resources;
- Monitoring requirements for the above issues

Recommendations for manure storage

To the TWG

- Review of what is to be considered as BAT.
- Analyse practices in the testing of sealing/leakage of lagoons with different types of bottom construction.
- Examine the costs and benefits of improvement options to provide clearer guidance (also for regulators).

To regulators

- Adopt an integrated approach to manure management, linking the manure production, storage and spreading to optimise process and environmental outcomes.
- Closer link between the development and implementation of good agricultural practices (e.g. by an agricultural authority) and the requirements of IPPC.
Problems concerning the Setting of permit conditions for manure spreading

• Making an accurate assessment of leaching potential in a specific area;
• Making an accurate estimation of the effect of measures;
• Confidentiality regarding the location of third party farms used for land spreading;
• Cost of soil testing (e.g. large number of third parties);
• IPPC permit is issued on the basis of the Act of environmental protection Law, but manure spreading is regulated by the Act of fertilisers and fertilisation. The implemented legal solutions cause a conflict of competences with appeals to court.

Recommendations for manure spreading

• Member States should adopt integrated approaches to manure management, from production to spreading;
• BREF should includes BAT and best practice in manure management/spreading;
• Authorities identify the key obligations that will arise from implementation of the WFD and ensure these are integrated with obligations on farmers with regard to manure spreading;
• Inspection activity should be undertaken during spreading
Housing systems

- Efficient animal housing means lower environmental impact of intensive animal breeding

↓ How?

Structure of pig stalls, type of flooring, manure storage, handling, ventilation systems, feed systems, production methods

↓ What?

Ammonia, odour and particles

Problems concerning the Setting of permit conditions for housing

- Defining what is BAT, with few reference farms, BAT data sheets, legal definition, etc;
- Classification about considering flushing channel system as BAT;
- Cost and timescale for implementation of any required changes for existing housing;
- Compliance with deadlines by operators.
Recommendations for housing systems

- European Commission translate the BREF’s to other languages rather than English;

- Permitting authorities should establish some conditions in permits to ensure that critical requirements related to housing are defined in such a way that compliance can be assured.

Air abatement

- End-of-pipe techniques should be used after other measures such as:
  - Housing design (flooring, ventilation, etc);
  - Methods for manure transfer;
  - Storage conditions.

- Air abatement systems are costly and may be considered as prohibitively expensive for routine application;

- There are no emission levels in the BREF. Use of ELV’s is only possible when diffuse sources are minimal and air abatement systems only work if the housing is a closed system, whereby all exhaust air can be treated;

- Permits include management or structural obligations to reduce emissions but rarely set ELV.
Air abatement

- Concern about effectiveness performance of the air abatement systems, which is much dependent on the operation by the farmer;
- Air scrubbers evolution's is beyond what is described in the BREF;
- The type of air scrubber can make a big difference, but it is hard to require a better one when there are no identified problems with odour or ammonia regulation;
- Difficult to prove in practice the linkage between air abatement systems and improvements in ammonia and odour emissions;
- Older housing have problems to adapt to air abatement systems resulting in significant non-point sources of pollution.

Problems concerning the Setting of permit conditions for air abatement

- Witch monitoring requirements to include in permits;
- General application of the bref’s is difficult;
- The majority of farms do not have point source emissions;
- There are some end-of-pipe systems being used in MS (e.g. Germany and The Netherlands) such as bio filters or air scrubbers, but most part of the countries reported that such techniques are not either being used by farms nor being actively considered by regulators for inclusion within permit conditions.
Recommendations for air abatement

- The primary focus should be on the environmental outcomes – ensuring that emissions do not cause adverse impacts. Therefore, the benefits and disadvantages of air abatement systems should always be compared to those from integrated process techniques.

Odour Assessment

- Odour is the principle concern that arises from local communities in relation to pig farms;
- Arises from the pig manure and the animals, therefore it can come from housing, manure transfer and storage and manure spreading;
- There are several approaches within MS.
Problems concerning the Setting of permit conditions for odour

- Reduction in stock numbers for odour emissions were required in a number of permits and these were appealed to the courts;
- Difficult to account the contributions of the different housing aspects and manure management to odour emissions and demonstrate that the odour is coming from the permitted site;
- Detection of odours can be complicated by local and unrelated land spreading and seasonality;
- Lack of legal enforcement of BREF;
- Cost of enzymes is an issue. Food producers do not guarantee to what extent the enzyme addition reduces odour.

Recommendations for odour assessment

- The BREF TWG should seek to quantify the level of reductions in odour that can be achieved by different techniques and how these can be used separately or in combination to give different desired outcomes;
- Authorities consider using odour management plans with operators, including all aspects of pig farm operation from production to manure spreading;
- Further work should be undertaken to establish the relationship between feed type and odour production.
Short list of most used BAT in MC

- Manure:
  - Manure storage capacity for 9 months or to comply with use of spreading;
  - Type of the materials concerning leakages;
  - Coverage and type of coverage;
  - Remote from water resources;
  - Lagoons with a lid/cover;
- Housing
  - Following general BAT requirements;
  - Ventilation systems;
  - Kind of ground in different use areas (sleeping, feeding);
  - Kind and quantity of drinking troughs;
  - System of removal of manure;
  - Type of equipment to feed and water;

Short list of most used BAT in MC

- Air abatement and housing
  - Permits do not involve air abatement or is rare;
  - Demands are set by ammonium and odour emissions;
  - Regular maintenance of technical equipment;
  - Special emission factor for particular types of pigs;
  - Liquid manure is incorporated into soil after spreading;
  - Materials that produce dust should be covered in storage;
  - Annual permissible limit on emissions;
- Odour
  - Odour management plan must be maintained and reviewed;
  - Artificial ventilation;
  - Cleanness and dryness of stables.
### Are operators obliged to use all BAT’s?

<table>
<thead>
<tr>
<th>Most part</th>
<th>Yes, always</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permits must be issued based on the BAT’s</td>
<td>When ELV thresholds are not fulfilled; In cases of justified conflicts</td>
<td>When a good environmental performance is already guaranteed by other means</td>
</tr>
</tbody>
</table>

Thank you

Please find more information in WWW.IMEP.EU/
### Ammonia volatilization from manure during storage and after application in the field

Sven G. Sommer

<table>
<thead>
<tr>
<th>Category</th>
<th>Store</th>
<th>Emissions, kg NH$_3$-N m$^{-2}$ a$^{-1}$</th>
<th>Emissions, % of TAN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No cover</td>
<td>No cover</td>
<td>Covered with surface crust, straw etc.</td>
</tr>
<tr>
<td>Cattle</td>
<td>Concrete store</td>
<td>1.44</td>
<td>9</td>
</tr>
<tr>
<td>Pigs</td>
<td>Concrete store</td>
<td>2.18</td>
<td>15</td>
</tr>
<tr>
<td>Fermented Slurry</td>
<td>Concrete store</td>
<td>2.33</td>
<td>28</td>
</tr>
</tbody>
</table>
Emission varies over the year

<table>
<thead>
<tr>
<th>Category</th>
<th>Emissions, kg NH₃-N m⁻² a⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermented Slurry</td>
<td>2.33</td>
</tr>
<tr>
<td>No cover</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Ammonia volatilization rates from three full-sized tanks containing digested slurry from a biogas plant; the slurry was either uncovered, covered with air-filled clay granules or a layer of straw.

Sommer 1997

New models

\[ F_A = K_{C1} \cdot A \cdot ([NH_3(g)] - [NH_3(a,g)]) \]

\[ [NH_3(g)] = \frac{1}{K_{NH3}} \cdot \frac{[TAN]}{1 + [H^+] / K_N} \]

\[ K_{C1} = 0.000612 \cdot u^{0.8} \cdot t^{0.382} \cdot l^{-0.2} \]

Input variables:
- TAN
- pH
- Temperature
- Windspeed
- Surface area of store
- Flow of slurry through the store
Ammonia emission from an uncovered Danish slurry store containing pig slurry

Temperature in solid manure heaps, (Webb et al. 2012)

Heap temperature, °C

T(D)=88-86*D, r²=0.75

Density of heap, Mg m⁻³
Ammonia emission from solid manure heaps (Web et al. 2012)

Ammonia emission, % of TAN

(\text{Ammonia emission, ln(% of TAN)}

\begin{align*}
\text{F(D)} &= 6.5 - 7.6 \times D, \quad r^2 = 0.498 \\
\end{align*}

Heap density, Mg m\(^{-3}\)

Ammonia emission from solid manure heaps (Web et al. 2012)

Trail hose reduction efficiency effect of crop height (Thorman et al. 2008)

\[ RE = 1 - \left( \frac{F_{NH3,c}}{F_{NH3,b}} \right) \]

\[ F(x) = 0.12 + 0.01x, \quad r^2 = 0.57. \]
Ammonia emission from slurry applied with trail hoses

(Thorman et al. 2008)

NH₃ emission, % TAN (NH₃+NH₄⁺)

Denmark

- Cattle slurry
- Pig slurry

Month

GOBSAT

- Emission factors should be related to:
  - composition of manure,
  - climate,
  - management

- Statistical models can do the job
- Mixed models may be a better option
- For both models categories we need data to:
  - Develop algorithms
  - Validate model
Manure Processing Activities in Europe - Project reference: ENV.B.1/ETU/2010/0007

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Henning L. Foged (Agropark)
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Karl M. Schelde (Agropark)
Jordi Palatsi (GIRO‐IRTA)
Albert Magri (GIRO)

Outline

• Objectives

• Presentation of the reports
  • Report I: Inventory of manure processing activities in Europe
  • Report II: Manure processing technologies
  • Report III: End and by-products from livestock manure processing
  • Report IV: Assessment of economic feasibility and environmental performance of manure processing technologies
Objectives

- The study aims to make an inventory of the actual manure processing activities in the EU. The inventory should indicate the amount of manure processed per Member State and differentiated per type of manure, the scale of operations (farm scale – medium scale- industrial scale), the operational processing techniques and indicate the kind and general characteristics of end and by-products as well as their recovery markets, and the assessment of different manure processing installations.

Report I: Inventory of manure processing activities in Europe

- Objectives: To make an inventory of the actual manure processing activities in the EU:
  - Processing technologies (45 listed technologies)
  - Manure processing type,
  - Amount of manure processed per MS (as well as kg N & P)
  - Scale of operations (farm, medium and industrial scale).

- Methodology: Digitalized survey (EU experts of each MS), supplemented with literature studies.
Methodology: The manure processing technologies (45) has been selected on the basis of the following criteria:

- Technologies designed to control processes that change the physical and/or chemical properties of the livestock manure, or in order to recover energy, to increase manure stability or to remove nutrients (N and/or P) from the main stream.
- Technologies which have not reached the marketing phase are also included.
- Technologies related to logistics handling of livestock manure, like pumping, storing, and spreading, are not considered.

Processing technologies considered:
Estimated amount of livestock manure produced from pigs, cattle and chickens in the EU Member States, divided on major livestock manure types. All figures in 1,000 tonnes per year (selected MS)

<table>
<thead>
<tr>
<th>EU Member State</th>
<th>Separated pig manure</th>
<th>Pig slurry</th>
<th>Pig deep litter</th>
<th>Separated cattle manure</th>
<th>Cattle slurry</th>
<th>Cattle deep litter</th>
<th>Separated poultry manure</th>
<th>Poultry slurry</th>
<th>Poultry deep litter</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>283</td>
<td>177</td>
<td>2972</td>
<td>1086</td>
<td>6635</td>
<td>12122</td>
<td>10106</td>
<td>6655</td>
<td>41</td>
<td>1337</td>
</tr>
<tr>
<td>Belgium</td>
<td>575</td>
<td>359</td>
<td>6039</td>
<td>216</td>
<td>8448</td>
<td>1564</td>
<td>12723</td>
<td>8488</td>
<td>83</td>
<td>2679</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>72</td>
<td>45</td>
<td>760</td>
<td>27</td>
<td>1882</td>
<td>348</td>
<td>2858</td>
<td>1882</td>
<td>50</td>
<td>1618</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>176</td>
<td>110</td>
<td>1851</td>
<td>66</td>
<td>4496</td>
<td>833</td>
<td>6827</td>
<td>4496</td>
<td>69</td>
<td>2217</td>
</tr>
<tr>
<td>Cyprus</td>
<td>43</td>
<td>27</td>
<td>451</td>
<td>16</td>
<td>281</td>
<td>18</td>
<td>42</td>
<td>18</td>
<td>8</td>
<td>268</td>
</tr>
<tr>
<td>Denmark</td>
<td>1142</td>
<td>714</td>
<td>11995</td>
<td>428</td>
<td>5133</td>
<td>950</td>
<td>7794</td>
<td>5133</td>
<td>55</td>
<td>1773</td>
</tr>
<tr>
<td>Estonia</td>
<td>114</td>
<td>21</td>
<td>154</td>
<td>13</td>
<td>147</td>
<td>124</td>
<td>174</td>
<td>124</td>
<td>5</td>
<td>162</td>
</tr>
<tr>
<td>Finland</td>
<td>128</td>
<td>80</td>
<td>1339</td>
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<td>3060</td>
<td>567</td>
<td>4646</td>
<td>3060</td>
<td>14</td>
<td>454</td>
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<tr>
<td>France</td>
<td>1368</td>
<td>859</td>
<td>14362</td>
<td>513</td>
<td>61948</td>
<td>11472</td>
<td>61948</td>
<td>11472</td>
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<td>Germany</td>
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</tr>
<tr>
<td>Spain</td>
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<td>1518</td>
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<td>911</td>
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<td>3715</td>
<td>20060</td>
<td>3715</td>
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### Livestock manure processing, distributed on separation technologies

<table>
<thead>
<tr>
<th>Separation by screws</th>
<th>Separation by sieves</th>
<th>Separation by drum filters</th>
<th>Air flotation</th>
<th>Separation by centrifuge</th>
<th>Natural settling separation</th>
<th>Total</th>
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<tbody>
<tr>
<td>617</td>
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# Draft report I: Results

### Livestock manure processing, distributed on separation technologies.

<table>
<thead>
<tr>
<th>Separation Technology</th>
<th>Number of plants</th>
<th>Average treated per installation, tons/year</th>
<th>Total treated amounts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composting / Flocculation</td>
<td>20</td>
<td>9</td>
<td>9800</td>
</tr>
<tr>
<td>Separation by grate</td>
<td></td>
<td></td>
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<td>Separation by screw pressing</td>
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<td>Separation by sieves</td>
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<td>Separation by centrifugation</td>
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</tr>
<tr>
<td>Separation by drum filters</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Natural settling separation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Flotation</td>
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<td></td>
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<tr>
<td>Natural settling separation</td>
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Total: 2135

### Additives

<table>
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<th>Additives</th>
<th>Number of plants</th>
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<tr>
<td>Acidification of liquid livestock manures</td>
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<tr>
<td>pH increasing (liming)</td>
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<td>Temperature and pressure treatment</td>
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<td>Applying other additives to manure</td>
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Total: 606

### Manure Processing Activities in Europe - Project Reference: ENV.L.2010/0007

Livestock manure processing, distributed on technologies concerning additives and other pre/1st treatments.

### Manure Processing Activities in Europe - Project Reference: ENV.L.2010/0007

Livestock manure processing, distributed on separation technologies.
Livestock manure processing, distributed on anaerobic treatment technologies.
Livestock manure processing, distributed on anaerobic treatment technologies

<table>
<thead>
<tr>
<th>Farm size installations</th>
<th>Small/medium size installations, treating &lt; 50,000 tons/year</th>
<th>Large-scale installations, treating &gt; 50,000 tons/year</th>
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<tbody>
<tr>
<td>2/5</td>
<td>Mesophilic anaerobic digestion</td>
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<tr>
<td>1/6</td>
<td>Thermophilic anaerobic digestion</td>
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</tr>
<tr>
<td></td>
<td>Total</td>
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</tr>
<tr>
<td></td>
<td>4692</td>
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<tr>
<td></td>
<td>21%</td>
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</table>

76% manure

Total treated amount: 49,034,000 t/y

- Nitrogen: 232,963 t/y
- Phosphorus: 56,217 t/y

Large increase in recent years (Italy, Germany, The Netherlands, Denmark)

Farm scale installation: 89% (4692 / 5256) 76% manure

Total treated amount: 49,034,000 t/y

Livestock manure processing, distributed on technologies for treatment of the solid fraction.

<table>
<thead>
<tr>
<th>Management activity</th>
<th>Number of plants</th>
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</table>
Livestock manure processing, distributed on technologies for treatment of the solid fraction.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Number of plants</th>
<th>Average treated per installation, tons/year</th>
<th>Total treated amounts, tonnes</th>
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</thead>
<tbody>
<tr>
<td>Small/large size</td>
<td>Farm size</td>
<td>Small/large size</td>
<td>Farm size</td>
</tr>
<tr>
<td>Treatment</td>
<td>installations</td>
<td>installations</td>
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Livestock manure processing, distributed on technologies for treatment of the liquid fraction.

<table>
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<th>Technology</th>
<th>Number of plants</th>
<th>Average treated per installation, tons/year</th>
<th>Total treated amounts, tonnes</th>
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</thead>
<tbody>
<tr>
<td>Small/large size</td>
<td>Farm size</td>
<td>Small/large size</td>
<td>Farm size</td>
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<tr>
<td>Treatment</td>
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<td>Evaporation</td>
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<td>Other</td>
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</table>

Related to bioprocess (composting, vermicompost & Biodrying, etc.)

Farm scale installation → 91% (1247 / 1373) → 55% manure

Total treated amount: 4,225,000 t/y
- Nitrogen: 52,914 t/y
- Phosphorus: 12,220 t/y

Livestock manure processing, distributed on technologies for treatment of the solid fraction.
### Livestock manure processing, distributed on technologies for treatment of the liquid fraction

#### Related Nitrification-Denitrification

Farm scale installation → 70% (229 / 328) 35% manure

Total treated amount: 1,118,000 t/y

- Nitrogen: 3,641 t/y
- Phosphorus: 364 t/y

### Report I: Results

#### Number of installations & size

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total</th>
<th>Large-scale</th>
<th>Small/Medium size</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Ultrafiltration</td>
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<tr>
<td>Reverse osmosis</td>
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</tr>
<tr>
<td>Concentration by vacuum evaporation</td>
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<tr>
<td>Electro-oxidation</td>
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<td>Ozonizing</td>
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<td>Aerobic Related Nitrification-Denitrification</td>
<td>705</td>
<td>23 6441</td>
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</table>

#### Manure, N & P processed

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total</th>
<th>Livestock manure (&gt;=1000 t/y)</th>
<th>Nitrogen (t/y)</th>
<th>Phosphorus (t/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation Additives Anaerobic Digestion Processing Solid Fract.</td>
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<tr>
<td>Anaerobic Digestion</td>
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<tr>
<td>Processing Liquid Fract.</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Livestock manure processing, distributed on technologies for treatment of the liquid fraction.
Report I: Conclusions

- It is being processed 6.2% of the livestock manure production in EU, equal to 86 million ton, containing 478,000 ton nitrogen and 112,000 ton phosphorus.

- The livestock manure processing technology process 146 million to livestock manure + other.

- The largest share of the livestock manure production is being processed in Greece (34.6%), Germany (14.8%) and Denmark (13.4%).

- There were 12 of the considered technologies that do not exist in commercial operation, or were not identified during the survey; for instance struvite or anammox.

Report II: Manure processing technologies

- Objectives: to describe and to characterize manure processing technologies.

- Methodology: Every process is explained in chart form, and every chart contains the following information (when available):
  - Objective,
  - Level of complexity, usual scale and innovation stage,
  - General diagram and pictures,
  - Theoretical fundamentals and process description,
  - Environmental effects,
  - Technical indicators (conversion efficiencies, energy consumption, reagents...),
  - Economical indicators (investment, quantifiable and non-quantifiable incomes, operational costs),
  - Selected literature references,
  - Real scale (commercial or pilot) references.
  - Combination of processes constituting technological strategies.
  - A classification of technologies based on its objectives are proposed.
  - Evaluation of technologies to be BAT candidates.
6.1: Composting of solid livestock manure or fibre fractions of slurries

**Objectives**

The main objective is to obtain a stable product with low moisture content and most of the initial nutrients, free of pathogens and seeds, called compost. The significant reduction of mass (water evaporation) reduces substantially transport costs.

**Level of complexity**

- Low
- Medium
- High complexity

**Applied to**

- On farm
- Medium
- Large
- Laboratory/research
- Pilot plant
- Industrial/commercial

**Example of chart: Composting**

**Benefits and/or emissions avoided**

- Improve N and P management
- Production of a high quality end-product (most of the nutrient and free of pathogens and seed)
- Odors, NH₃
- Odors, NH₃, CH₄, N₂O
- CH₄ emissions storages
- Odor abatement
- N availability
- Pathogens reductions
- Leaks of biogas
- Equipment and protocols to control emissions (mixtures, O₂ control)

**Associated emissions**

- CO₂ emissions (energy consumption)
- CH₄ emissions (fossil fuels)
- CO₂ avoided (fossil fuels)
- N availability
- Digestate storage
- Equipment and protocols to control biogas leakages
- Fertilizer properties of digestates
- Emissions storage and application

**Further research**

- Quantification of the uncontrolled emissions
- Operational conditions to minimize emissions (mixtures, O₂ control)
- Equipment and protocols to control biogas leakages
- Fertilizer properties of digestates
- Emissions storage and application
### Identification of processes that could be BAT candidates.

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<td>Electrocoagulation</td>
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<td>Separation by drum filters</td>
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<td>Treatment of the fibre/solid fraction</td>
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<td>Y</td>
<td>C</td>
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<td>41A</td>
<td>Vermicomposting</td>
<td>Y</td>
<td>Y</td>
<td>C</td>
<td>CBAT</td>
<td></td>
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<td>42</td>
<td>Bio drying</td>
<td>Y</td>
<td>Y</td>
<td>C</td>
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<td>43</td>
<td>Thermal drying</td>
<td>Y</td>
<td>C</td>
<td>C</td>
<td>CBAT</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Pelletizing</td>
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<td>Y</td>
<td>C</td>
<td>CBAT</td>
<td></td>
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<tr>
<td>45</td>
<td>Pelletizing</td>
<td>Y</td>
<td>Y</td>
<td>C</td>
<td>CBAT</td>
<td></td>
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<td>46</td>
<td>Compression</td>
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<td>Y</td>
<td>C</td>
<td>CBAT</td>
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<tr>
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<td>Thermal gasification</td>
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<td>48</td>
<td>Pyrolysis</td>
<td>N</td>
<td>N</td>
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<td>49</td>
<td>Wood gasification</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td></td>
</tr>
</tbody>
</table>

A BAT document on manure processing technologies should contain the unitary processes to be used and guidelines for its good operation practices.

---

### Report III: End and by-products from livestock manure processing

- End and by-products from livestock manure processing were classified in **11 groups** according to their chemical composition, content of nutrients, etc.

- Around **130 datasets to describe the chemical composition** of end and by-products were gathered,

- The **20 chemical parameters**
Types and amounts of end and by-products from livestock manure processing in EU (the amounts are based on estimates of number of manure processing installations in EU Member States and the amount of livestock manure they process):

1. Separation solids: 2,679 th. Tonnes/year
2. Separation liquids: 14,109 th. Tonnes/year
3. Thermal and chemically treated manure: 7,473 th. Tonnes/year
4. Digestate: 88,039 th. Tonnes/year
5. Manure compost: 3,253 th. Tonnes/year
6. Dried manure and pellets: 967 th. Tonnes/year
7. Ashes and charcoal: 124 th. Tonnes/year
8. Filter water: 1,732 th. Tonnes/year
9. Manure processing effluents: 6,080 th. Tonnes/year
10. Manure concentrates: 1,154 th. Tonnes/year
11. Air cleaning sludge: -

Heavy metals like Cu and Zn are especially more concentrated in the end and by-product groups “Manure compost” and “Dried manure and pellets”

The quality of the digestate is a mirror of the quality of the inflow substrates.

Therefore, if the quality of the digestate should be regulated, the most obvious and natural way to do is via regulation of the products that are anaerobically digested (inputs to the plant).

Further research on the behavior of end and by-products (nutrient bioavailability, emissions, etc) is required.
Objectives: To assess the economic feasibility and environmental performance of the most common techniques for both large and small scale installations including a few case studies.

Methodology: 7 case studies of manure processing plants, considering:

- Problem to be solved and level of efficiency obtained.
- Characterisation of the mass balance.
- Characterization of the energy balance.
- Characterization of the environmental effects and estimation of equivalent CO₂ emissions.
- Characterization of the economical performance.

1. Morsø Bioenergi / biogas production on basis of decentralised slurry separation
2. Slurry acidification, near Randers

Report IV: Results

3. Conversion to mineral fertiliser, Kumac Mineralen

Report IV: Results
4. Nitrification and de-nitrification (NDN) at Calledetenes, Spain

5. Combination anaerobic digestion – evaporation and drying, Garrigues, Spain
6. Manure anaerobic digestion and nitrogen recovery by stripping. 
Ihan, Domžale (Slovenia)

7. Combination anaerobic digestion – composting, Girona, Spain
**Report IV: Results**

- **Plant localization:**
  - 3 Spain
  - 2 Denmark
  - 1 The Netherlands
  - 1 Slovenia

- **Capacities:** 10,000 m³/y to 390,000 m³/y

- **Energy balances:** +128 kWh/m³ to -800 kWh/m³

- **Investment cost:** 6.6 €/m³ to 163.6 €/m³

- **Processing cost:** 0.66 €/m³ to 33.72 €/m³

- **CO₂eq Reduction:** -- kg CO₂eq/m³ to 82.5 kg CO₂eq/m³

---

**Report IV: Conclusions**

- **Treatment plants usually combine different unitary process technologies (up to 10).**

- **Wide variation** in the characteristics, aim and performance of the 7 plants described.

- **Plants aiming recover energy** and nutrients seem to be wide spread.

- **CO₂eq avoided** varies widely between plants. **A deepest analysis for each technology and combinations is required.**

- **Subsidies** and “feed in” electrical tariffs are the key factor for plant economy.

- **No general conclusion about economy of scale. A bigger sample is required.**
any question?

http://agro-technology-atlas.eu/knowledge.aspx
PP15

Manure spreading - efficacy, agronomic impacts and costs of reduced-NH₃ emission manure application methods

J Webb (Ricardo-AEA)
John Morgan and Brian Pain (Creedy Associates)

Content of talk

- Advantages of reducing NH₃ emissions following application to land
  - compared with reducing at other stages of manure management
- Effectiveness of reduced-NH₃ emission spreading techniques
- Cost effectiveness of reduced NH₃ spreading
- Impacts of reduced-NH₃ spreading on N₂O and NO₃⁻
Advantages of reducing emissions following application to land

• Emission following land spreading one of the two largest sources in the UK
• The largest source in many national inventories

NH₃ '000 t

Advantages of reducing emissions following application to land

• NH₃ lost ‘upstream’, e.g. buildings and stores may be lost ‘downstream’ e.g. spreading, if no further measures taken
  • emissions largely cease when absorbed by soil
• Reduces emissions at final stage of manure management, i.e. spreading
Effectiveness of reduced-NH₃ emission spreading techniques

Abatement efficiencies

- Spreading manures by reduced-NH₃ techniques gives some of the greatest emission reductions

- Whilst being among the most cost-effective methods
  - immediate/rapid incorporation of broadcast slurry and FYM
  - open-slot, shallow injection
  - band spreading by trailing shoe
  - band spreading by trailing hose

Average abatement efficiencies, % reduction compared with broadcast surface application

- Mean
- -1 SD
- +1 SD

T Hose | T Shoe | OS Inj
Cattle FYM – autumn 2003

kg/ha

Surface

Disc

Tine

Plough

Mins

Open slot injection

Advantages

- most efficient abatement for slurry on grassland
- demonstrated to increase crop uptake of slurry-N
- can be cost-effective at recent N fertilizer prices

Disadvantages

- cannot be used in growing arable crops
- cannot be used on shallow or stony soils
- can cause sward damage
- although average effectiveness greatest, results are variable
### Trailing shoe

**Advantages**
- almost as effective as OS injection
- increases crop N Uptake
- can be cost-effective at recent N fertilizer prices

**Disadvantages**
- only suitable for grassland
- needs grass high enough to cover slurry
- ‘thatch’ can collect on coulters requiring operator to stop and clear

### Trailing hose

**Disadvantages**
- on average only about half as effective as TS and OS injection
- but equally expensive
- not likely to be cost-effective even at recent N fertilizer prices
- improved N uptake not demonstrated

**Advantages**
- flexible
- can be used for grass as well as arable
- and when slurry applied to cereal crops at stem erect stage abatement can be c. 60%
Effectiveness of reduced-NH$_3$ emission spreading techniques

- For all machines cost-effectiveness depends upon volume to be spread.
- Hence other than for large farms application by contractor may be more practical
- And will allow access to a greater range of machines

Cost-effectiveness of abatement techniques

- Reduced-NH$_3$ emission application methods have some of the greatest abatement potentials, and are among the most cost-effective
  - but uptake of reduced-NH$_3$ emission spreading equipment has been limited
  - question is being asked, in relation to revision of Gothenburg protocol, have the agronomic benefits of reduced-NH$_3$ emission spreading equipment been fully identified?
  - do current cost estimates need revising?
### N Fertilizer break-even price

<table>
<thead>
<tr>
<th></th>
<th>T Hose</th>
<th>T Shoe</th>
<th>OS Inject.</th>
<th>Imm Inc. pig FYM, plough</th>
<th>Imm. Inc. broiler, disc</th>
</tr>
</thead>
<tbody>
<tr>
<td>N conserved kg m³</td>
<td>0.2</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Add cost £ per m³/t</td>
<td>0.46</td>
<td>0.59</td>
<td>0.69</td>
<td>0.34</td>
<td>0.80</td>
</tr>
<tr>
<td>Break even £/kg N</td>
<td>2.22</td>
<td>1.43</td>
<td>1.43</td>
<td>0.57</td>
<td>0.14</td>
</tr>
<tr>
<td>AN price £/t</td>
<td>766</td>
<td>493</td>
<td>493</td>
<td>197</td>
<td>48</td>
</tr>
</tbody>
</table>

Based on:
32% TAN emitted from 6% pig slurry, 3.6 kg N/m³, 60% TAN
68% TAN emitted from pig FYM, 7.0 kg/t N, 14% TAN
52% TAN emitted from broiler manure, 30.0 kg/t N, 60% TAN
UK AN price - £300/t (Aug 2012); Urea £365

### Manure spreading – current practice UK

- Accounts for 24% of total emissions from livestock
- Most manure, both slurry and solid, is applied to the surface
  - on arable land incorporation may be within a few hours but more usually left for days or weeks
- About half of manures are applied to grassland and most remain on the surface until washed into soil/grown over by grass
Immediate incorporation of solid manures - FMAVIS

- The FieldMAVIS model was created to estimate the efficacy of immediate incorporation of solid manures by different techniques
  - plough, disc, tine, harrow
- The approach was similar to that of the CESAR model of slurry incorporation
  - but gave different results
- Incorporation by disc, tine etc., was never more effective than by plough

Increased N uptake from reduced NH$_3$ spreading

- Injection of slurry has been reported to increase ANR compared with broadcast surface application by an average of 11%
  - when no damage was caused to the crop by injection
Trailing shoe

- The NFRV has been reported to be strongly influenced by the month in which manure was applied
  - increasing from 0.30 to 0.40 when applied in April
  - but from 0.14 to 0.24 when applied in June
- Later grass cuts do not use N as efficiently as the first cut
  - this is due to less crop growth
  - perhaps more NH$_3$ volatilization under warmer conditions and
  - greater denitrification in autumn compared with spring or because of immobilization associated with root death
- Results support the conclusion that better utilization can be achieved by applying N in diminishing amounts over the growing season

Trailing hose

- The reduction in NH$_3$ volatilization increases with increasing crop height
  - N recovery from slurry is also expected to be greater when using TH in growing crops
- Application on bare soil by TH has little effect on NH$_3$ losses
- The results of application to grassland are intermediate
Impact on NO$_3$· leaching
broiler manure, Lancs and Suffolk
black=NH$_3$, white=NO$_3$, kg/ha

Impact of solid manure incorporation on direct N$_2$O (%N)
12 month - clay soil

% of N applied
UK Pilot farms study

- In 1998 MAFF, now Defra, co-funded the purchase of a range of reduced-emission spreaders to enable some commercial farmers to use them over a 5 year period
- Farmers were also compensated for the additional costs of immediate incorporation of solid manures

Pilot farms
- overall conclusions

- All the farmers were still using reduced-NH$_3$ emission machines after 10 – 11 years
- and most still have their original machine
- one had stopped using an injector in favour of a TH
- Most claim a positive impact on their business
  - especially in terms of saving on fertilizer costs
  - flexibility in when and where to apply slurry
    - not always clear if savings in fertilizer are entirely due to the machine or could have been achieved by more considered use of splashplate spreading
    - it appears that the machine encourages, and makes it easier, for farmers to use slurry more effectively
- Most could not could have afforded to initially purchase without subsidy from the project
- Nor afford to replace the machine
Farmer experience - Creedy

• Information from telephone interviews with farmers, contractors and machinery suppliers
  ▪ included some who participated in Pilot Farms project
• Feedback from farmers during manure management workshops
  ▪ and extensive day-to-day advisory contact with farmers
• Most information relates to use of reduced-NH$_3$ emission application machines
• Many farmers incorporate manures
  ▪ but little evidence they do this soon enough after spreading to have a significant impact on NH$_3$ emissions
• ‘Soft’ measures not often used to reduce NH$_3$ emissions
  ▪ Some farmers are reluctant to spread in the evening because of a greater likelihood of complaints about odour when neighbours are home
UK NH₃ emissions in 2011 – by source/activity

Abatement efficiencies
Measuring gaseous emissions from animal houses and storage facilities

Mélynda Hassouna and Paul Robin

What does motivate the measurements?

- Scientific research: understanding the emitting processes, kinetics, influencing parameters, optimize the nutrients use by minimizing the losses.
- Pollution abatement: development of mitigation techniques, certification of the efficiency.
- Policy-making: national inventories, certification of BAT.
Agricultural emissions

Be aware of Specificities:

Examples for animal house
- High spatial and temporal variability
- Temperature gradients
- Animal
- Air composition (many different gases and PM)
- Ventilation
- Farmer practices

Choosing the method in function of the context but also the purpose!

Reference methods
- Continuous measurement
- Studies of emitting processes
- Development of measuring methods
- Scientists

Simplified Methods
- Intermittent measurement + models
- Low-cost methods
- Efficiency of BAT/mitigation options and environmental certification
- Emission-factor acquisition
- Scientists, agricultural engineers, monitoring and certification offices

Control methods
- Intermittent measurement
- Low-cost methods
- Emission levels checking
- Agricultural engineers, monitoring and certification offices and livestock technicians, farmers
Many possibilities

Many methods

Intrusive

Non intrusive

Global

(house/farm level)

Intrusive

Non intrusive

Local

No standard protocol

- Results of measurements depend on:
  - User (skills and time spent)
  - Sampling (means, position, frequency, duration)
  - Sensors (adequation, sensitivity, precision, position, calibration)

- Results for emissions depend on:
  - Sampling points (dealing with spatial variability)
  - Data processing
  - Interpolation and extrapolation (dealing with temporal variability)
  - Validation

Protocols description should be accurately described

Small differences can induce huge differences on emission data
Infrared spectrometry for concentration measurement in animal house

Infrared Photoacoustic spectrometry

Selection of the gases with optical filters

Compensation of interferences is possible if corresponding optical filters are installed

Dairy cattle

Gas concentrations: INNOVA 1412

2 PTFE sampling tubes at the same location

<table>
<thead>
<tr>
<th>Period A</th>
<th>Period B</th>
<th>Period C</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 days</td>
<td>2 days</td>
<td>0.5 day</td>
</tr>
<tr>
<td>• Cows</td>
<td>• Slurry</td>
<td>• Silage</td>
</tr>
<tr>
<td>• Slurry</td>
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<td>(manually mixed)</td>
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</table>

<table>
<thead>
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<th>Gas</th>
<th>PAS-A2</th>
<th>PAS-A3</th>
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<tbody>
<tr>
<td>Ammonia</td>
<td>973 / 0.2ppm</td>
<td>979 / 0.5ppm</td>
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<tr>
<td>Carbon dioxide</td>
<td>982 / 1.5ppm</td>
<td>Not measured</td>
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<tr>
<td>Methane</td>
<td>969 / 0.4ppm</td>
<td>969 / 0.4ppm</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>985 / 0.03ppm</td>
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<tr>
<td>Acetic acid</td>
<td>Not measured</td>
<td>971 / 0.03ppm</td>
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<tr>
<td>1-Propanol</td>
<td>Not measured</td>
<td>975 / 0.2ppm</td>
</tr>
<tr>
<td>Ethanol</td>
<td>Not measured</td>
<td>973 / 0.1ppm</td>
</tr>
</tbody>
</table>

Infrared Photoacoustic spectrometry

Interferences!

Gas 1
Gas 2
Gas 3
Filter A
Filter B
Filter C
Experiment 2

**H₂O Concentrations**

Identical kinetics and concentrations levels

Experiment 2

**CH₄ Concentrations**

(same filters but different compensations)

- Identical kinetics and a small shift due to calibration
- High concentrations and oscillations during period A
- A lower peak in period C than in period A

Batfarm workshop – 19 and 20/03/2013 – Rennes
**NH3 Concentrations**

### Different filters and different compensation

- Strong differences between signals for period A and C
- Observation of strong peaks for period with silage and with/without cows
- Same concentration level and kinetic for period B
- With PAS-A3, NH3 concentrations have low variations

**Peaks of Ammonia observed with PAS-A2 not due to ammonia emissions**

**Batfarm workshop – 19 and 20/03/2013 – Rennes**

**Interferences : overestimation of NH3 concentrations with PAS-A2**

NH3 concentrations with PAS-A2 are overestimated and mainly due to Ethanol and Acetic Acid emitted by silage
## No standard protocol

<table>
<thead>
<tr>
<th>Reference Method</th>
<th>No.</th>
<th>Year</th>
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<tbody>
<tr>
<td>Kavolelis, 2006</td>
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<td>Webb et al., 2012</td>
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<td>Webb et al., 2012</td>
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<td>Mosquera et al., 2006</td>
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<td>Dolle et Capdeville, 2000</td>
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<td>Zhang et al., 2005</td>
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<td>Van’t Ooster, 1994</td>
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<td>Van Duinkerken et al., 2011</td>
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<td>Smell et al., 2003</td>
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<td>Pollet et al., 1998</td>
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<td>Pereira et al., 2010</td>
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<tr>
<td>Monteny et al., 2002</td>
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<tr>
<td>Kavolelis, 2006</td>
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<tr>
<td>Dolle et Capdeville, 2000</td>
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<tr>
<td>Bjørg et al., 2011</td>
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<tr>
<td>Zhang et al., 2005</td>
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<td>Sanee et al., 2011</td>
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<td>Philips et al., 1998</td>
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<td>Pereira et al., 2010</td>
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<td>Ngwabie et al., 2009</td>
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<td>Dore et al., 2004</td>
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<td></td>
</tr>
<tr>
<td>Dolle et Capdeville, 2000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### N-NH3 emissions (g N-NH3/dairy/day)

| 0 | 50 | 100 | 150 | 200 | 250 |

## No reference method and source

- Many available methods but data quality ??

### No reference method !

### No validation of the measuring methods !

- Reference systems and sources coupled with interlaboratories comparison could help to the validation

- Combination of different measuring methods
Comparison and calibration

Nitrogen (mostly ammonia)

<table>
<thead>
<tr>
<th>Tank 1</th>
<th>Tank 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass balance</td>
<td>mass balance</td>
</tr>
<tr>
<td>emission</td>
<td>emission</td>
</tr>
</tbody>
</table>

Tank 1:

- NH₃N + NO₃N

NH₃N | N₂O₃N
---|---
C₂ | 0.97 | 0.0048 | C₁ | 0.34 | 0.0005

Measurements with both chambers underestimate N losses.

Carbon

<table>
<thead>
<tr>
<th>Tank 2</th>
<th>Tank 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>mass balance</td>
<td>mass balance</td>
</tr>
<tr>
<td>emission</td>
<td>emission</td>
</tr>
</tbody>
</table>

Tank 2:

- CH₄ + CO₂

CO₂_C | CH₄_C
---|---
C₂ | 0.3 | 11.2 | C₁ | 8.3 | 8.3

Measurements with both chambers are close to the mass balance.

No reference method and source

Laboratory conditions not real conditions (complex gas mixture)

Reference source

Comparison and calibration
No reference method and source

- Uncertainty evaluation

- Uncertainty is difficult to estimate, it depends on several measuring details
- Improved description of measuring procedure can help to improve uncertainty calculations; repeated controls are necessary
- General procedures for uncertainty estimates need further work

Take back home

- Several methods exist since many years; inaccuracy of description can induce differences in results
- Procedures for emission measurement should be described in a way allowing Quality Assurance / Quality Control, and comparisons between laboratories, when it is required
- Standards procedures (?) should result from existing well-known methods, discussed by people who practice them in reference laboratories. International context.
- Uncertainty evaluation should be done for all the methods to certify the efficiency of mitigation techniques and to compare results from literature
Thank you for attention!
From candidate BAT description to BAT conclusion

<table>
<thead>
<tr>
<th>Description of candidate BAT</th>
<th>Uniform and complete description of candidate BAT in chapter 4 BREF (all items and data needed for BAT assessment, for BAT conclusion and enforcement/permitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition of Reference Techniques</td>
<td><strong>Baseline</strong> for all technical categories under the scope of IED</td>
</tr>
<tr>
<td>BAT assessment</td>
<td>Assessment of cand. BATs by a combined approach: <strong>pre-screening</strong> of <strong>consensual BATs</strong> + <strong>expert judgement supported by other methods</strong> against <strong>Reference Techniques</strong></td>
</tr>
<tr>
<td>BAT conclusions</td>
<td>Deriving BAT conclusions and BAT-AELs</td>
</tr>
<tr>
<td>➤ Sound and comparable data are a precondition for assessment and derivate BAT conclusions and emission levels</td>
<td></td>
</tr>
<tr>
<td>➤ <strong>Need for international harmonized sampling and measuring protocols (VERA)</strong></td>
<td></td>
</tr>
</tbody>
</table>
COMMISSION IMPLEMENTING DECISION
of 10 February 2012

3.3. Individual BAT conclusions with associated environmental performance levels

Environmental performance levels associated with BAT may include:

— emission levels,
— consumption levels,
— other levels (e.g. abatement efficiency).

An environmental performance level associated with BAT will be included where there is a sound basis for doing so. This will be done based on the information exchanged by the TWG taking into account the quantity and quality of the plant-specific data received during the exchange of information.

The environmental performance levels associated with BAT will be expressed as ranges, rather than as single values. A range may reflect the differences within a given type of installation (e.g. differences in the grade/purity and quality of the final product, differences in design, construction, size and capacity of the installation) that result in variations in the environmental performances achieved when applying BAT.

Example of an individual BAT conclusion which includes emission levels associated with BAT (BAT-AELs)

4.2. In order to reduce VOC emissions from process AA, BAT is to use one or a combination of the techniques given below.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>aa</td>
<td>new plants</td>
</tr>
<tr>
<td>b</td>
<td>bb</td>
<td>existing plants</td>
</tr>
<tr>
<td>c</td>
<td>cc</td>
<td></td>
</tr>
</tbody>
</table>

The BAT-AELs for VOC are:

— For new installations: 10–20 mg C/Nm³ as a daily average under reference conditions xx, yy, ...
— For existing installations: 20–30 mg C/Nm³ as a daily average under reference conditions xx, yy, ...
Example of possible BAT-AELs for the IRPP sector (EIPPCB, Brussels 25. February 2013)

BAT-associated emission levels (BAT-AEL) for ammonia emissions from the housing of growers/finishers (pigs)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>BAT</th>
<th>BAT-AELs (kg NH₃-N per animal place/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃ expressed as N</td>
<td>Housing systems as reported in BAT X, group of techniques (a), (b)</td>
<td>1.2 – 2 (¹)</td>
</tr>
<tr>
<td></td>
<td>Air treatment systems as reported in BAT X, group of techniques (c)</td>
<td>&lt;0.75</td>
</tr>
</tbody>
</table>

(¹) The lower end of the range is associated with the application of BAT to new or largely rebuilt housing.

(²) The applicability of air treatment systems may require a case-by-case assessment due to technical and economic considerations.

Proposal for Reference Techniques (Æ no distinction between climatic zones = “applicability constraints”)

<table>
<thead>
<tr>
<th>Animal/techn. category</th>
<th>Reference Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigs</td>
<td></td>
</tr>
<tr>
<td>- Mating and gestating sows</td>
<td>Insulated, forced ventilated housings; partly slatted floor, single phase feeding</td>
</tr>
<tr>
<td>- Farrowing sows</td>
<td>Insulated, forced ventilated housings; crates, partly slatted floor, single phase feeding</td>
</tr>
<tr>
<td>- Rearing of piglets</td>
<td>Insulated, forced ventilated housings; fully slatted floor, single phase feeding</td>
</tr>
<tr>
<td>- Fattening pigs</td>
<td>Insulated, forced ventilated housings; fully slatted floor, single phase feeding, slurry storage over the whole production period (123 days)</td>
</tr>
<tr>
<td>Poultry</td>
<td></td>
</tr>
<tr>
<td>- Laying hens</td>
<td>Insulated, forced ventilated housings, litter based floor housing system (deep litter system with 1/3 of the total area as scratching area, 2/3 as deep pit with manure storage over the whole period - 393 days); single phase feeding</td>
</tr>
<tr>
<td>- Pullets (rearing of young hens)</td>
<td>See laying hens</td>
</tr>
<tr>
<td>- Broiler</td>
<td>Insulated, forced ventilated housings, litter based floor housing system</td>
</tr>
<tr>
<td>- Broiler breeder</td>
<td>Insulated, forced ventilated housings, litter based floor housing system</td>
</tr>
<tr>
<td>- Turkeys</td>
<td>Insulated, forced ventilated housings, litter based floor housing system</td>
</tr>
<tr>
<td>- Ducks</td>
<td>Insulated, forced ventilated housings, litter based floor housing system</td>
</tr>
</tbody>
</table>
**Technical feasibility**
- Applicability (new/existing installations, site conditions, climate)
- Operability (functional safety)
- Practical experience (use at farm level)
- Product quality
- Worker safety

**Environmental performance**
- Emission air
- Emission soil/water
- Energy demand
- Water demand
- Other resources

**Animal welfare / animal health**

**Economical viability**
### Indicators for assessment

(Proposal for a methodology for the assessment of candidate BAT in order to determine BAT for the IRPP BREF review 18 July 2011)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Nutrition</th>
<th>Pigs and poultry housing</th>
<th>Manure storage</th>
<th>Manure processing</th>
<th>Manure land-spreading</th>
<th>Air treatment techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Odour</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CH₄</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N/P losses</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N (nitrogen)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (phosphorus)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu, Zn, other elements</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other emissions</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand/production</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water demand</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**“whole-farm BAT approach”/combined techniques:**
currently an issue of scientific development - will play an important role in the future; due to strong doubts only demonstrated for few combinations of techniques in chapter 4

---

**Covered by mass balance method**

---

### Covered by mass balance method

(Proposal for a methodology for the assessment of candidate BAT in order to determine BAT for the IRPP BREF review 18 July 2011)

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Nutrition</th>
<th>Pigs and poultry housing</th>
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<th>Manure processing</th>
<th>Manure land-spreading</th>
<th>Air treatment techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Odour</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CH₄</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N/P losses</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>N (nitrogen)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P (phosphorus)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu, Zn, other elements</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other emissions</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td>e.g. noise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand/production</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water demand</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand of other resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount and hazardousness of by-products</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The EIPPCB and participants shared the proposal of **not including BAT AELs for CH₄ and N₂O emissions**, but address the issue concerning these substances whenever considered necessary in Chapter 4 (Brussels 25. Feb. 2013)
BAT assessment – simplified approach
→ mainly based on expert judgement

1. **pre-screening of obvious or consensual BATs by expert judgement**: possibly (examples):
   - phase feeding (nitrogen/phosphorous adapted feeding according to animal needs)
   - pig fattening: vacuum system (BAT 2003)
   - laying hens: aviary system with manure belt (BAT 2003)
   - covering of slurry stores with solid or floating cover (technical feasibility provided) (BAT 2003)

2. by expert judgement in combination with a scoring system:
   → according to VITO (adapted and amended)
   supported by
   → BAT Support tool
   (→ LCA-like mass balance-method)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Technical feasibility</th>
<th>Environmental performance</th>
<th>Animal welfare</th>
<th>Economic feasibility</th>
<th>Assessment BAT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proven</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>+</td>
<td>yes</td>
</tr>
<tr>
<td>T2</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>yes</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Scoring** based on quantitative/qualitative information
(→ chapter 4 of BREF) and expert judgement. /.. Reference Techn.:
BAT SUPPORT

= Specific Support Action under the EU 6th Framework Programme on Research, Technological Development and Demonstration

Duration: March 2007 to February 2011

- **Czech Republic**: Martin Dedina, Research Institute of Agriculture Engineering (VUZT)
- **Denmark**: Niels Lundgaard, Thorkild Frandsen, Institute for Agro Technology and Food Innovation (AgroTech)
- **France**: Laurence Loyon, Fabrice Guiziou, Colin Burton, French Institute of Agricultural and Environmental Engineering Research (CEMAGREF)
- **Germany**: Isabel Benda, Helmut Döhler, Brigitte Eurich-Menden, Ewald Grimm, Stefan Hartmann, Association for Technology and Structures in Agriculture e.V. (KTBL)
- **Italy**: Laura Valli, Guiseppe Bonazzi, Research Centre for Animal Production (CRPA)
- **The Netherlands**: Nico Ogink, Stichting Dienst Landbouwkundig Onderzoek (DLO)
- **Poland**: Tadeusz Kuczynski, Institute of Agricultural Engineering (IBMER)
- **Spain**: Carlos Pineiro, PigCHAMP Pro Europa S.A. (PigCHAMP)
- **Switzerland**: Harald Menzi, Swiss College of Agriculture (SHL)

+ additional experts (environment, animal welfare) / TWG / EIPPC-Bureau

---

**BAT SUPPORT Assessment system – basic ideas**

- development of a simple, structured and comprehensive assessment and rating system for the main environmental effects of techniques applied in livestock farming
  - related to the different stages of production:
    - Housing (animal categories), storage, treatment, application
- considering cross-media effects (scoring system)
- based on the methodology published in the BREF "Intensive Livestock Farming" (ILF 2003)
  - improving it
  - using similar criteria
  - evaluation against a **Reference System (RS)**
- resuming the approach of the German study "National evaluation for animal housing systems in Germany"
  - qualitative evaluation of main indicators and influencing factors for quantitative data are often missing and/or are very variable
  = kind of a simplified emission model
Assessment system – basic ideas

1. **if possible** quantitative assessment: comparing data on environmental performance (assessed system vs. Reference System – RF)
   - benchmark could be taken into account (e.g. ammonia emission 3 kg per pig place and yr.?, reduction efficiency of at least 20 %?)

2. **alternatively** Qualitative assessment: structured expert judgment if quantitative data are not available
   - rating of the main properties that influence the environmental indicators (as documented with the documentation system)
   - additional measures for emission reduction (e.g. N-reduced feeding, improvement climatization/air quality of the housings)
     - can be accounted for up to 20 % (40%?) in general or
     - up to the factor that has been proofed by measurements

---

### Qualitative assessment of environmental impacts

<table>
<thead>
<tr>
<th>Indicator</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM (PM_{10})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrous oxides</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-P- losses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water demand</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

at the example of ammonia

⇒ other effects are assessed in a similar way
Qualitative assessment of environmental impacts - Ammonia

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td>Building construction / ventilation system</td>
<td>... rising indoor temperature level</td>
<td>low – outdoor induced climate, natural ventilation</td>
<td>0</td>
<td>FSF small group</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>medium – insulated housing, forced ventilation</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>high – uninsulated housing, forced ventilation</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Factors influencing environmental performance are rated by points (0, 1, 2) → simple emission model → the higher the score the higher the emission potential, energy demand etc.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pen design</td>
<td></td>
<td>... increasing emitting surface area due to small groups / unstructured flooring</td>
<td>large group – multi area pen, separate dunging area, individual housing with fixation (sows only)</td>
<td>0</td>
<td>FSF small group</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>large group – single area pen, no separate dunging area</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>small group – multi area pen, separate dunging area</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>small group - single area pen, separate dunging area</td>
<td>2</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
Qualitative assessment of environmental impacts - Ammonia

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td>Building construction / ventilation system</td>
<td>... rising indoor temperature level</td>
<td>low – outdoor induced climate, natural ventilation medium – insulated housing, forced ventilation high – uninsulated housing, forced ventilation</td>
<td>0</td>
<td>1 FSF small group</td>
</tr>
<tr>
<td></td>
<td>Pen design</td>
<td>... increasing emitting surface area due to small groups / unstructured flooring</td>
<td>large group – multi area pen, separate dunging area; individual housing with fixation (sows only) large group – single area pen, no separate dunging area small group - multi area pen, separate dunging area small group - single area pen, no separate dunging area</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Manure removal frequency</td>
<td>... increasing indoor manure storage time</td>
<td>no storage or daily removal storage time ≤ 2 months storage time &gt; 2 months</td>
<td>0</td>
<td>1 FSF small group</td>
</tr>
</tbody>
</table>

Qualitative assessment of environmental impacts - Ammonia

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td>Building construction / ventilation system</td>
<td>... additional emitting surface area</td>
<td>no yard structured yard with dunging area, frequent manure removal unstructured yard, no frequent manure removal</td>
<td>0</td>
<td>1 FSF small group</td>
</tr>
<tr>
<td></td>
<td>Pen design</td>
<td>... additional emitting surface area</td>
<td>no yard structured yard with dunging area, frequent manure removal unstructured yard, no frequent manure removal</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Manure removal frequency</td>
<td>... additional emitting surface area</td>
<td>no yard structured yard with dunging area, frequent manure removal unstructured yard, no frequent manure removal</td>
<td>0</td>
<td>1 FSF small group</td>
</tr>
</tbody>
</table>

| Yard                    | ... additional emitting surface area | no yard structured yard with dunging area, frequent manure removal unstructured yard, no frequent manure removal | 0      | 1 FSF small group         |
Qualitative assessment of environmental impacts - Ammonia

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
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<tbody>
<tr>
<td>Ammonia / Odour</td>
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<td></td>
<td></td>
<td></td>
<td>FSF small group</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pen design</td>
<td></td>
<td></td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Manure removal frequency</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Yard</td>
<td></td>
<td>additional emitting surface area</td>
<td>no yard</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>structured yard with dunging area, frequent manure removal</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>unstructured yard, no frequent manure removal</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>additional measure for emission reduction</td>
<td></td>
<td></td>
<td>high efficiency additional measure (&gt; 40%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>medium efficiency additional measure (&gt; 20%)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>low efficiency or no additional measure</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total Sum</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

Qualitative assessment of environmental impacts (simplified) also for other effects

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Energy demand relevant factor / &quot;demand increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy demand</td>
<td>Building construction</td>
<td>... insufficient thermal insulation of the housing</td>
<td>high (insulation of roof, walls, bottom)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>medium (insulation only of roof)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>low (no insulation)</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ventilation system</td>
<td>Increasing energy demand</td>
<td>natural ventilation system or combined ventilation system (natural ventilation + backup ventilation)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>forced ventilation system</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>forced ventilation system with increased pressure drop</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Heating system</td>
<td>... increasing energy demand for heating</td>
<td>additional heating not necessary</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>zone heating system</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>room heating system</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
**Qualitative assessment of environmental impacts (simplified)**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Energy demand relevant factor / &quot;demand increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy demand</td>
<td>Building construction</td>
<td></td>
<td>additional heating not necessary equivalent to animal welfare standard more than animal welfare standard</td>
<td>0</td>
<td>FSF small group</td>
<td>1 1</td>
</tr>
<tr>
<td></td>
<td>Ventilation system</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heating system</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>space provided</td>
<td></td>
<td>... increasing space to be heated</td>
<td></td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>additional energy demand</td>
<td></td>
<td>... application of energy consuming add. techniques</td>
<td>low or no additional energy demand medium additional energy demand (&lt; 20%) high additional energy demand (&gt; 20%)</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>integrated additional measure for saving energy</td>
<td></td>
<td>... the absence of additional measures for saving energy</td>
<td>high efficiency (&gt; 40%) medium efficiency (&gt; 20%) Low efficiency / no measure</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**Qualitative assessment of environmental impacts**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
<td>FSF small group</td>
<td>4</td>
</tr>
<tr>
<td>PM (PM$_{10}$)</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>N-P-losses</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Energy demand</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Water demand</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

* evaluation system as proposed is harmonized with the animal health and welfare assessment.
Summarizing the environmental assessment (proposal)

- most techniques will not be “best” for all indicators
  - some kind of categorization will be necessary in order to consider cross-media effects

<table>
<thead>
<tr>
<th>Assessment result</th>
<th>BAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prerequisite for BAT</strong> (= knock-out criterion): reduced ammonia emissions compared to the reference system (RS)</td>
<td></td>
</tr>
</tbody>
</table>

- total sum of all indicators and all single indicators rated equal to or better than RS
  - A (***)

- total sum of all indicators rated equal to or better than RS, but not all of the single indicators
  - B (**)  

- total sum of all indicators rated inferior to RS
  - C (*)
  
(⇒ Category C = conditional BAT, e.g. depending on site conditions?)
## Qualitative assessment of environmental impacts

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Technique module</th>
<th>Emission relevant factor / &quot;emission potential increasing with...&quot;</th>
<th>Factor specification</th>
<th>rating</th>
<th>Reference system</th>
<th>Assessed system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia / Odour</td>
<td></td>
<td>In this case:</td>
<td></td>
<td></td>
<td>7 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- reduced ammonia emissions compared to the reference system (RS) and</td>
<td></td>
<td>5 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM (PM&lt;sub&gt;10&lt;/sub&gt;)</td>
<td></td>
<td>- an advantage referring to energy demand</td>
<td></td>
<td>5 5</td>
<td>10 10</td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td>- but a higher potential for PM emission</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N-/P- losses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand</td>
<td></td>
<td></td>
<td></td>
<td>5 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water demand</td>
<td></td>
<td></td>
<td></td>
<td>3 3</td>
<td>35 31</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>+ total sum of all other indicators rated equal to or better than RS, but not all of the single indicators.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Æ B (**)

---

## BAT SUPPORT

### 2. Animal Health and Welfare Assessment

(an issue that is of high public relevance e. g. in Germany)
Mass balance / whole farm approach (Wenzel et al. 2013, University of Southern Denmark)

Focus on N-flow and GHG* over the whole farm – but controversial opinions of many MS

* weak database, no relevance for permitting

The calculations of the mass balance approach (Wenzel et al. 2013)

<table>
<thead>
<tr>
<th>Substance categories</th>
<th>Algorithm used for estimation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia NH$_3$-N</td>
<td>$NH_3$-N = EF (%) * N slurry (e.g. ex animal)</td>
<td>Literature on EFs</td>
</tr>
<tr>
<td>GHG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CH_4$</td>
<td>$CH_4[kg] = VS[kg] * B_0 * 0.67 * MCF$</td>
<td>IPCC (2006)</td>
</tr>
<tr>
<td></td>
<td>• VS is ab animal&lt;br&gt;• $B_0$ : maximum $CH_4$ producing capacity [m$^3$/kg VS ab animal] <em>(from IPCC table)</em>&lt;br&gt;• 0.67: $CH_4$ density [kg/m$^3$]&lt;br&gt;• MCF: $CH_4$ conversion factor [%] <em>(from IPCC table)</em></td>
<td></td>
</tr>
<tr>
<td>$N_2O$-N (direct)</td>
<td>$N_2O$-N = EF * kg N in slurry ex animal</td>
<td>IPCC (2006)</td>
</tr>
<tr>
<td>$N_2O$-N (indirect, volatilization)</td>
<td>$N_2O$-N = EF * (kg $NH_3$-N + $NO_x$-N volatilized)</td>
<td>IPCC (2006)</td>
</tr>
<tr>
<td>N leaching from field</td>
<td>$N_{leach} = 0.4 * (Tot-N_{storage} - NH_3-N_{field emission})$</td>
<td>Danish model*</td>
</tr>
</tbody>
</table>

* From 32% to 43% leaching was found via an elaborated model (Wesnæs et al. 2009)
Assessment - Results mass balance approach

- advantage of the mass balance method: additional possibility to take the process chain into account

- But weak database for CH₄ and N₂O – decision not including BAT

AELs for CH₄ and N₂O emissions – cross-media effects

- results could also be qualitatively described according to chemophysical principles and derived by expert judgment based on the understanding of these mechanisms and cause-effect relationships
  - N-Input reduced
    - Emission potential reduced over all stages
  - N chemically bonded e.g. by acidification
    - Emission potential reduced over all/subsequent stages
  - N accumulated / reduced evaporation (e.g. cooling)
    - Emission increased on subsequent stages
    - additional measures necessary then

Target groups: + politics
VERA (Verification of Environmental Technologies for Agricultural Production) – since 10/2008

**Actors**

**DK**
EPA, Danish Standards (VERA-Sekretariat), Danish Pig Producer, Agrotech, Uni Aarhus

**NL**
VROM (Env. Ministry), University Wageningen

**DE**
BMELV, (BMU), KTBL, vTI, DLG, Uni Kiel, Uni Hohenheim

+ F, UK, BE??

**Objective**

- Verification of environ. technologies:
  - emission reduction efficiency
  - operational stability

- No assessment / no certification
  = National requirements; e.g.
    - DK: Danish Technology List
    - NL: Regeling ammoniak en veehouderij (Rav)

- Standardisation of sampling and measuring methods
  + framework conditions

- EN ISO 7025- accredited laboratories only with agric. expertise

- International/mutual acceptance of test results
International Test Protocols

- Air cleaning technologies
- Livestock housing and management systems
- Slurry separation technologies
- Covers and other mitigation technologies for reduction of gaseous emission from stored manure
- Technologies for the reduction of gaseous emissions from land applied manure

**In preparation**
- Biogas technology

---

**Test Protocol**

for

Livestock Housing and Management Systems

**Full-scale tests:**
- Case-control → 2 farms
- No case control possible (e.g. naturally ventilated housings) → 4 farms
Structure of the Test Protocol „Housing systems“

Foreword ..........................................................................................................................
List of abbreviations .......................................................................................................  
Summary .............................................................................................................................
1. Introduction ....................................................................................................................
2. Scope ..............................................................................................................................
3. Terms and definitions ...................................................................................................
4. System description .......................................................................................................  
5. Requirements ................................................................................................................
   5.1 Pre-testing or full testing of a technology ....................................................  
   5.2 Requirements on organisation of the test activities .............................
   5.3 Requirements on the test facility .................................................................
   5.4 Requirements for the test organisation .....................................................
   5.5 Test design and sampling strategy ............................................................
   5.6 Measurement parameters ................................................................................
   5.7 Data treatment, calculation and evaluation of emissions..............................
6. Test report and evaluation ...........................................................................................  

Framework conditions animal housing 1/2

Table 1: Review of requirements per animal category

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Dairy cattle</th>
<th>Sows</th>
<th>Farrowing sows/piglets</th>
<th>Weaners</th>
<th>Fattening pigs</th>
<th>Laying hens</th>
<th>Broilers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd composition</td>
<td>90/90/30 %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permitted weight range, (kg)</td>
<td>6-35</td>
<td></td>
<td></td>
<td>25-115</td>
<td></td>
<td></td>
<td>0.05-3</td>
</tr>
<tr>
<td>Animal occupation rate of test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>compartment (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum number of animals in the test</td>
<td>30 cows</td>
<td>20</td>
<td>10 sows</td>
<td>50</td>
<td>50</td>
<td>750</td>
<td>1000</td>
</tr>
<tr>
<td>compartment before testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal period of use of housing</td>
<td>2 months</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>system before testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Framework conditions animal housing 2/2

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Dairy cattle</th>
<th>Sows</th>
<th>Farrowing sows / piglets</th>
<th>Weaners</th>
<th>Fattening pigs</th>
<th>Laying hens</th>
<th>Broilers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed composition</td>
<td>Minimum 50 % roughage</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Feed requirements: CP/energy</td>
<td>Minimum 160 g CP kg(^1) dry matter</td>
<td>See Annex G</td>
<td>See Annex G</td>
<td>See Annex G</td>
<td>See Annex G</td>
<td>See Annex G</td>
<td>See Annex G</td>
</tr>
<tr>
<td>Minimum production requirements</td>
<td>20 kg per cow and day</td>
<td>22 piglets per sow and year</td>
<td>10 piglets per litter</td>
<td>350 g per day</td>
<td>760 g per day</td>
<td>300 eggs per hen and year</td>
<td>Min 1900 g at max. 45 days</td>
</tr>
<tr>
<td>Technical management factors that may affect emissions should be recorded</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Test-Design - Case-control studies
(one farm, forced ventilation system)

Table 2: Sampling strategy for testing livestock housing and management systems in cases where case-control within a farm is possible

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of compartments/housing units for sampling</td>
<td>Two different farm locations, each farm location having at least one case and one control compartment/housing unit.</td>
</tr>
<tr>
<td>Minimum size of units for sampling</td>
<td>The unit size must be representative for farms in the participating countries (cf. 5.3).</td>
</tr>
</tbody>
</table>
| Measurement periods                            | At each farm location:  
  Ammonia, odour and dust (average for year):  
  • Six measurement days in one year;  
  Odour (specific for DK):  
  • Six measurement days with outdoor temperatures above 16 °C during sampling\(^1\). |
| Sampling sites                                  | Simultaneously sampling in the case and the control compartments/housing units. Management in the case and the control compartments/housing units should be the same. |

\(^1\) All odour samples sampled at temperatures above 16 °C may be included as part of the required minimum of 6 additional odour samples stated in Table 1.
Test-Design - **keine case-control Studien**
(zwischen Betrieben; freie Lüftung)

Table 3: Sampling strategy for testing livestock housing systems in cases where case-control within a farm is not possible (e.g. naturally ventilated dairy farms)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Minimum requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of test farms</td>
<td>Four different farm locations</td>
</tr>
<tr>
<td>Minimum size of units for sampling</td>
<td>The unit size must be representative for farms in the participating countries (cf. 5.3).</td>
</tr>
<tr>
<td>Measurement periods</td>
<td>At each farm location:</td>
</tr>
<tr>
<td></td>
<td>Ammonia, odour and dust (average for year):</td>
</tr>
<tr>
<td></td>
<td>- Six measurement days in one year.</td>
</tr>
<tr>
<td></td>
<td>Odour (specific for DK):</td>
</tr>
<tr>
<td></td>
<td>- Six measurement days with outdoor temperatures above 16 °C during sampling¹.</td>
</tr>
<tr>
<td>Sampling sites</td>
<td>Simultaneously sampling in the case and the control compartments/housing units.</td>
</tr>
<tr>
<td></td>
<td>Management in the case and the control compartments/housing units should be the same.</td>
</tr>
</tbody>
</table>

¹ All odour samples sampled at temperatures above 16 °C may be included as part of the required minimum of 6 additional odour samples during tests in DK.

Distribution of the measurement days within the year and the production cycle

[Graphs showing distribution of measurement days within the year and the production cycle]
**Measurement parameters**

**Table 4: Primary measurement parameters**

<table>
<thead>
<tr>
<th>Parameter [Units]</th>
<th>Sampling conditions (where, how and how often)</th>
<th>Measuring method (reference to the method)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia [mg m⁻³]</td>
<td>• Minimum number and distribution of sampling days (refer to section 5.5).</td>
<td>• Photo-acoustic monitor (NDIR)</td>
</tr>
<tr>
<td></td>
<td>• Cumulative sampling over 24 hours.</td>
<td>• FTIR spectrometer</td>
</tr>
<tr>
<td></td>
<td>• Continuous measuring methods: based on hourly values (24 samples).</td>
<td>• NOx-chemiluminescence monitor</td>
</tr>
<tr>
<td></td>
<td>• Sampling location: Air inlet and air outlet.</td>
<td>• Impinger system</td>
</tr>
<tr>
<td></td>
<td>• Correction of background concentration.</td>
<td>• Open path Tunable Diode Laser (TDL).</td>
</tr>
<tr>
<td>Odour [OU m⁻³]</td>
<td>• Minimum number and distribution of sampling days (refer to section 5.5).</td>
<td>EN 13726/AC:2006 Air quality – Determination of odour concentration by dynamic olfactometry</td>
</tr>
<tr>
<td></td>
<td>• Min. three samples per sampling day.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sampling time: Between 30 and 120 minutes.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sampling equipment: Nafion bags</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sampling location: Cross-section of air outlets, preferably mixed sample.</td>
<td></td>
</tr>
<tr>
<td>Dust - Total - PM10 - PM2.5 [mg m⁻³]</td>
<td>• Minimum number and distribution of sampling days (cf. section 5.6).</td>
<td>Standards for dust measurements exist:</td>
</tr>
<tr>
<td></td>
<td>• Continuous measuring methods: based on hourly values (24 samples).</td>
<td>EN 13284-1:2001</td>
</tr>
<tr>
<td></td>
<td>• Sampling time: 24 hours for PM10/2.5.</td>
<td>EN 13288-2:2004</td>
</tr>
<tr>
<td></td>
<td>• Sampling location: Air inlet and air outlet.</td>
<td>EN 15299:2007</td>
</tr>
<tr>
<td></td>
<td>Measurement of PM10 and PM2.5 is optional for methodological reasons.</td>
<td>Other instruments can also be used, e.g. Impactor, optical (light scattering) instruments, microbalancing</td>
</tr>
</tbody>
</table>

**VERA - current status (2012)**

**DK**
- 10 on-going/finalized tests, 5-10 additional tests planned
- mainly air cleaning systems and livestock housing systems (e.g. acidification), but also application and covers for manure stores
- 1st VERA Verification Statement in 10/2012

**NL**
- Acceptance and application (RAV technique list) since 02/2012

**DE**
- So far there is no direct link between VERA and the environmental regulation in Germany → authorities of the federal states
- In general: increasingly requests on tests by manufacturers not only from DK, but from NL and DE also (air cleaner/housing systems)
Difficulties to overcome

- **Different methods for emission sampling and measurements** and definition of emission (ranges/units) – insufficient/missing international standards:
  - Odour: EN 13725 – with / without dust filter, different levels /units (OU/(LU s), OU/(ap s))
  - PM: applied standard

- **Different legal regulations**, e.g. animal welfare
  - ammonia concentration: e.g. DE < 20 ppm → influence from ventilation rate
  - ventilation rates

- **Different agricultural practise**:  
  - cattle housing – young cattle / heifers kept in the same building as cows, time of pasture

- **Accreditation** according to EN ISO 17025 – not every participating state has such laboratories with agricultural expertise (universities,...?)

VERA – planned activities

- **Research and development projects under ICT-AGRI** (Information and Communication technologies)
  1. Harmonized sampling and measurement methods for odour, ammonia and dust emission including ventilation rate naturally ventilated housings
  2. Research and development of methods for test of technologies for biogas production

- Integration of VERA in the EU Environmental Technology Verification Scheme (ETV)?
  (http://www.eu-etv-strategy.eu/index.htm)

- **confidence building measures, e.g.**
  - Conducting „multi-country“ tests
  - mutual site visits during measurements
Many thanks for your attention!
Ewald Grimm, KTBL Darmstadt
e.grimm@ktbl.de / +49-6151-7001-156
A guide on Good Environmental Practices for Breeding

Nadine GUINGAND
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Reconciling the environment with livestock management
BATFARM workshop
Irstea, Rennes, France, 19-20 March, 2013

A Technical Network « Livestock and Environment »

**Purpose** – Proposition and transfer of tools for the management of animal production system in order to improve their environmental balances

**Focus** - multi-sector, multi-criteria, multi-scale approach

- Air Pollution, GHG Effects, Nuisances
  - 

- Reduction of natural resources
  - Water, Energy

- Pollutions
  - Water, soil
  - 

- Pathogens
  - 

Unit ➔ farm ➔ Territory

BATFarm workshop, Rennes, 19-20 March, 2013
A Technical Network « Livestock and Environment »

Research
INRA
UMR SENA, UMR PL, SRA, URH, LEE, UEASM, UEPF,
LPA, UEFE et UEPF Lusignan,
UMR SAS, LBE, Agronomie Clermont

Technical Institutes
ARVALIS, CETIOM,
IFIP, IDELE, ITAVI,
UNIP

Education
Agrocampus Ouest
CREPA

Chambers of Agriculture
Pays de la Loire,
Bretagne (pôle herbivore porc et agronomie)

A guide on Good Environmental Practices for Breeding

One tool provided by the Technical Network « Livestock and Environment »

BATfarm workshop, Rennes, 19-20 March, 2013
A guide on Good Environmental Practices for Breeding

Pigs
Cattle
Poultry

BATfarm workshop, Rennes, 19-20 March, 2013
A guide on Good Environmental Practices for Breeding

An overview of the technical knowledge currently available on how to reduce one or more environmental issues due to animal production

A list of 65 Good Environmental Practices for Breeding

A Good Environmental Practices for Breeding (GEPB)

- a technique, equipment and/or a management
- permitting to reduce the environmental impact on water, air and/or soil.
- Very close to BAT (IED)
- Specific to the French national context
Selection criteria for GEPB

- Technical reliability of the implementation of the practice
- Technical maintenance
- Technical efficiency per environmental parameter
- Cross effects
- Investment and operating costs

Most of the GEPBs are listed in the IRPP BREF and are BAT

- Data provided are specific to the french context (technical and economic aspects)

Some GEPBs are not BAT in the 2003 version of the IRPP BREF

- More recent data permitting to assess the technique
A guide for technicians and farmers

- In french
- A « synthetic » document
- Including techniques for cattle production
- Easy to use… in the form of data sheets
- Easy to read… the main information organized in principal headings
Easy to read

Environmental benefits
Cross effects
Investment and operating costs
Applicability
Incentives factors

Easy to read

To find out more
Hypertext link to the summary per animal production
Available in two versions

**In bound version**
- Available upon request from IFIP ([www.ifip.asso.fr](http://www.ifip.asso.fr))
- or IDELE ([www.idele.fr](http://www.idele.fr))
- or ITAVI ([www.itavi.asso.fr](http://www.itavi.asso.fr))

**In electronic version (free)**
- Downloading from the website of the Technical Network [www.rmtelevagesenvironnement.org](http://www.rmtelevagesenvironnement.org)

BATfarm workshop, Rennes, 19-20 March, 2013
BATFARM SOFTWARE:
A support tool in the selection of environmental strategies in livestock operations in the Atlantic Region

European Workshop* IRSTEA, Rennes (20th March 2013)

INDEX

- Software Objective
- Software Structure
- Case Study
- Final comments
OBJECTIVE

- To develop a tool that helps selecting the most appropriate **environmental strategies** in a particular livestock operation

  - To calculate **emissions** (NH₃, CH₄ and N₂O) taking into account the **BATs applied**
  - **Comparison** of different BATs options
  - Pigs, Laying hens, broilers, dairy cows, fattened calves and beef cows

SOFTWARE STRUCTURE AND OPERATION

- **Empirical and mechanistic models**
- Designed for **farm-scale use**
- Inputs typically well **known by the farmer**
- The entire animal production process
SOFTWARE STRUCTURE AND OPERATION

- **Emissions** and **consumptions** from different **environmental strategies implemented on farms** (on-farm measurements obtained at regional scale)

- **Default values**, modifiable by the user, have been included to develop **versatile** and **user-friendly** software.

SOFTWARE STRUCTURE AND OPERATION

- **Regionalizable** input values for zootechnical data, climatic information and emission factors have been defined in order to reflect different climatic and production conditions within Portugal, Spain, France, UK and Ireland.
As a result, both nutrient balance and gaseous emissions are calculated throughout the different stages of the animal production system based on particular farm management criteria as defined by the user.
SOFTWARE STRUCTURE AND OPERATION

HOUSING STAGE

- Animal nutrient balance, considering zoo-technical and nutritional data
  - Different nutritional management (adjustment of protein and phosphorus)
- Gas emission: the type of floor, the frequency of slurry removal, slurry temperature, nitrogen dilution in the slurry, ventilation rates, bedding characteristics, grazing periods and other best available techniques (BATs)

SOFTWARE STRUCTURE AND OPERATION

STORAGE STAGE

- Gas emission, nutrient and mass balance
  - Climatic conditions
  - Covers
  - Additives
SOFTWARE STRUCTURE AND OPERATION

TREATMENT STAGE

- Gas emission, nutrient and mass balance
- **24 possible processes:**
  - mechanical solid/liquid separation techniques
  - aerobic treatment
  - anaerobic digestion
  - gravity decantation
  - composting

SOFTWARE STRUCTURE AND OPERATION

LANDSPREADING STAGE

- Gas emission and nutrients in the soil
  - Climatic conditions
  - The equipment used for manure application
  - Manure Incorporation
  - Dry matter content in the slurry
SOFTWARE STRUCTURE AND OPERATION

Faecal Indicators Organisms (FIOs)

- An assessment of each stage (3-stage qualitative scale)

NEUTRAL  GOOD  VERY GOOD

SOFTWARE STRUCTURE AND OPERATION

OTHER OPTIONS...

- Introducing parameters to calculate the cost of the environmental techniques selected
- Comparison between two different scenarios
SOFTWARE STRUCTURE AND OPERATION

- **MAIN OUTPUTS OF THE MODEL:**
  - Feed and water consumption
  - Animal production
  - NH₃, N₂O, CH₄ emissions
  - Solid and liquid manure production and composition
  - Nutrients in soil
  - Effects on FIOs

- **TYPE OF REPORTS:**
  - Each Stage
  - All the farm
  - Farm comparison (when two situations)

CASE STUDY

- **Farrow to finish swine farm,** with pre-fattened and fattened pig production.

- Number of sows housed (including gilts): 270, 1050 pre-fattening places (from 5 to 22 kg) and 1200 fattening places (from 22 to 110 kg)

- This farm is located in Spain under **Continental Mediterranean conditions** (annual mean temperature, 14°C; annual rainfall, 354 mm, annual average wind speed 0.7 ms⁻¹ and annual average relative humidity 63.4%)

- Two situations compared: **STANDARD vs BATs**
## CASE STUDY

### STANDARD SITUATION vs. BATs SITUATION

<table>
<thead>
<tr>
<th>HOUSING</th>
<th>STANDARD SITUATION</th>
<th>BATs SITUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply manure in a way</td>
<td>Supply manure in a way</td>
<td>Supply manure in a way</td>
</tr>
<tr>
<td>in fattening and</td>
<td>in fattening and</td>
<td>in fattening and</td>
</tr>
<tr>
<td>fattening buildings</td>
<td>fattening buildings</td>
<td>fattening buildings</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Storage</th>
<th>STANDARD SITUATION</th>
<th>BATs SITUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>With manual spreading</td>
<td>With manual spreading</td>
<td>With manual spreading</td>
</tr>
<tr>
<td>No cover</td>
<td>No cover</td>
<td>No cover</td>
</tr>
<tr>
<td>Single tank</td>
<td>Single tank</td>
<td>Single tank</td>
</tr>
<tr>
<td>Mixing</td>
<td>Mixing</td>
<td>Mixing</td>
</tr>
<tr>
<td>Shovel input every month</td>
<td>Shovel input every month</td>
<td>Shovel input every month</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LANDSPREADING</th>
<th>STANDARD SITUATION</th>
<th>BATs SITUATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donation</td>
<td>Donation</td>
<td>Donation</td>
</tr>
<tr>
<td>No irrigation</td>
<td>No irrigation</td>
<td>No irrigation</td>
</tr>
</tbody>
</table>

### Ammonia Emission

![Ammonia Emission Chart](chart.png)

- **Standard** vs. **BATs**
- **35% Emission reduction**

### Chart Details

- **Ammonia Emission** in kg NH3
  - Housing
  - Storage
  - Landspreading
  - Total
  - Standard
  - BATs
CASE STUDY

19% Emission reduction

Nitrous Oxide Emission

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>BATs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td>Storage</td>
<td>200</td>
<td>180</td>
</tr>
<tr>
<td>Landspreading</td>
<td>150</td>
<td>130</td>
</tr>
<tr>
<td>Total</td>
<td>450</td>
<td>345</td>
</tr>
</tbody>
</table>

CASE STUDY

21% Emission reduction

Methane Emission

<table>
<thead>
<tr>
<th></th>
<th>Standard</th>
<th>BATs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing</td>
<td>10000</td>
<td>8500</td>
</tr>
<tr>
<td>Storage</td>
<td>15000</td>
<td>13000</td>
</tr>
<tr>
<td>Total</td>
<td>25000</td>
<td>21500</td>
</tr>
</tbody>
</table>

kg N2O
kg CH4
CASE STUDY

- Gas emission is higher during summer, due to higher temperatures.
- NH₃: emissions are increased during the landspreading periods.

CASE STUDY

- IMPACT ON FIOS:

<table>
<thead>
<tr>
<th>STAGE</th>
<th>STANDARD</th>
<th>BATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOUSING</td>
<td>🙃</td>
<td>👍</td>
</tr>
<tr>
<td>STORAGE</td>
<td>🙃</td>
<td>👍</td>
</tr>
<tr>
<td>LANDSPREADING</td>
<td>🙃</td>
<td>👍</td>
</tr>
</tbody>
</table>
CASE STUDY

OTHER DESTACABLE ASPECTS:

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>STANDARD</th>
<th>BATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein consumption fatt. (g/kg LW)</td>
<td>484</td>
<td>402</td>
</tr>
<tr>
<td>Phosp. consumption fatt. (g/kg LW)</td>
<td>15.7</td>
<td>13.9</td>
</tr>
<tr>
<td>Quantity of slurry (t per year)</td>
<td>4241</td>
<td>4241</td>
</tr>
<tr>
<td>N (kg/t)</td>
<td>4.3</td>
<td>3.8</td>
</tr>
<tr>
<td>P (kg/t)</td>
<td>1.2</td>
<td>1</td>
</tr>
<tr>
<td>Nitrogen Fert. Units lost (kg N)</td>
<td>4086</td>
<td>2467</td>
</tr>
<tr>
<td>% N excreted soil</td>
<td>59</td>
<td>67</td>
</tr>
</tbody>
</table>

FINAL COMMENTS AND FUTURE WORK

- **FREE** and **PUBLIC** access
- Expected Availability: **AUTUMN 2013**
- Further test will be necessary to **VALIDATE THE RESULTS** provided by this tool.
Thank you for your attention