Waste air purification systems for pig housing systems

Developments, implementation and public opinion

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Contents

- Background: population and livestock concentrations, environmental issues
- Air treatment technology in pig production
  - basic principles and application
  - removal efficiencies
- Regulations and verification of technology use
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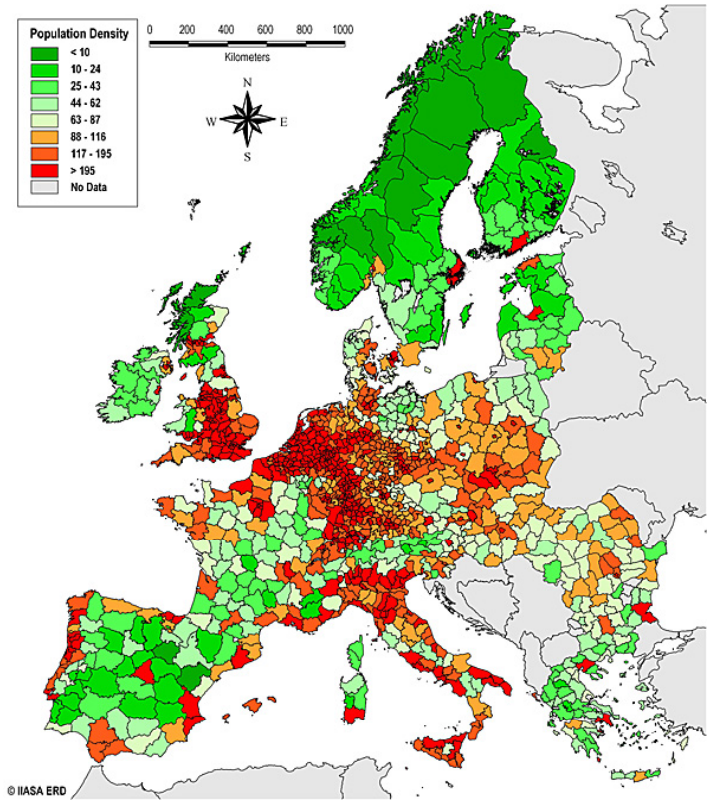
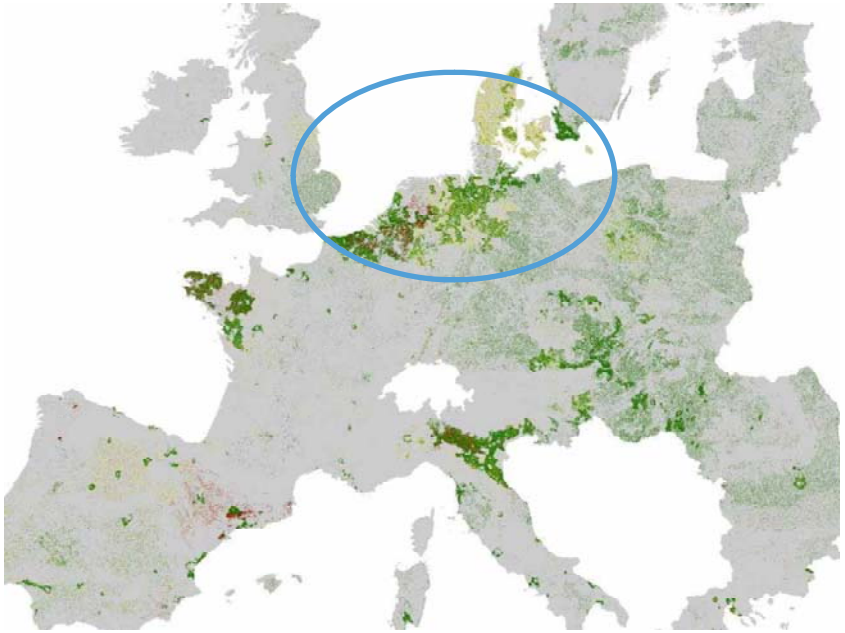
Europe: population and livestock density

Population density



Pig density



Neumann et al., 2008

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Environmental issues in high livestock density areas

High livestock density in Northern Europe causes air quality problems in areas with high population density:

- Ammonia emission: biodiversity loss, indirect health impact
- Odour emission: nuisance, health impact?
- Fine dust emissions: health impact
- Bioaerosols: health impact?
- Greenhouse gases: climate effects

Environmental problems related to NH3 emissions

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

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

Effects of N deposition: loss of biodiversity

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

- Housing systems
- Manure application techniques

Odour nuisance: the most directly experienced impact

- Nuisance levels in animal production areas in the Netherlands: 10 – 12 % (proportion of residents that experienced odour nuisance one or more times per year)
- Increasing opposition against large scale pig operations: potential odour annoyance
- Relation between odour nuisance and health effects not clear

Fine dust (PM10) and bioaerosols

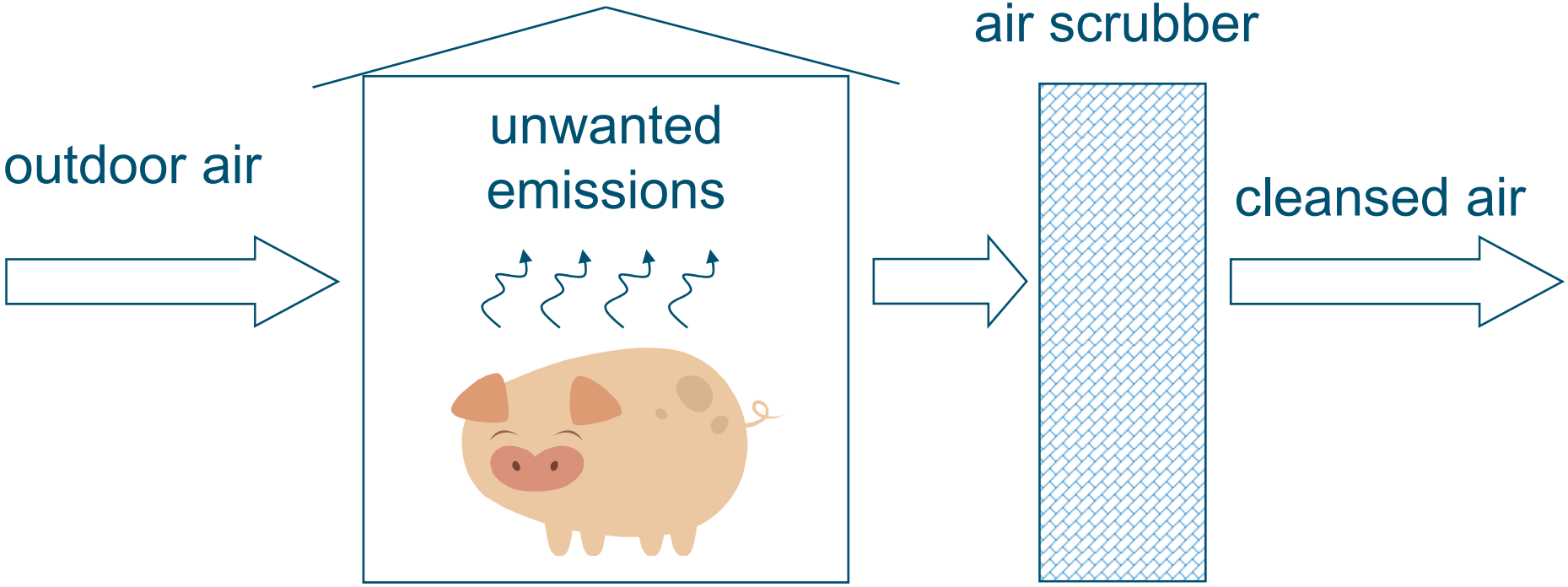
- Animal production significant contributor to fine dust generation (Particulate Matter: PM10 and PM2.5)
- In areas with high background levels: large operations may exceed threshold levels PM10, especially litter-based systems produce PM10
- Bioaerosol emissions: endotoxins, antibiotic resistant bacteria (MRSA) a.o.: risk levels for surrounding residential area difficult to evaluate

Treatment of exhaust air necessary in high density areas

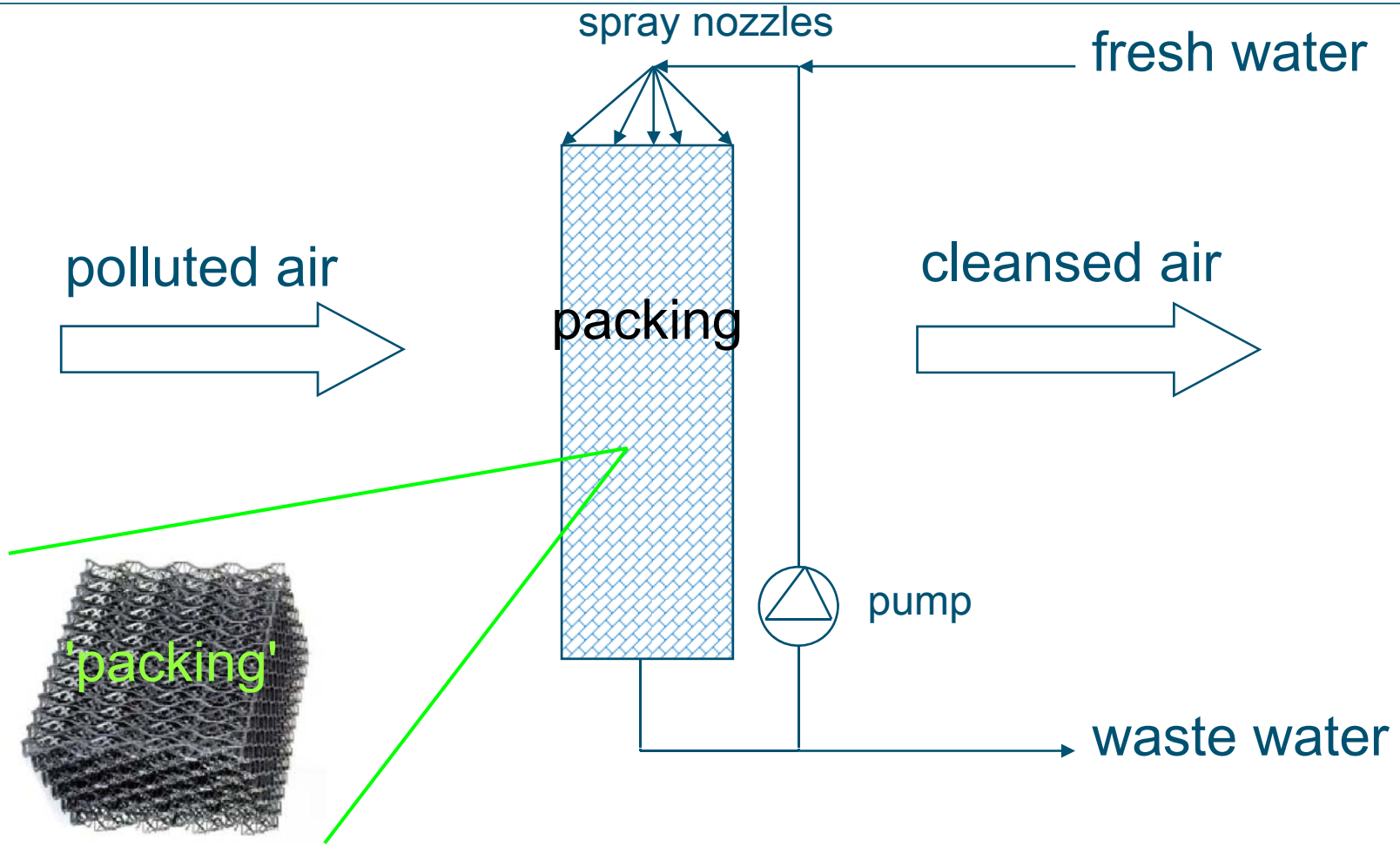
- Strict emission standards for existing and new facilities require substantial emission reductions:
  - ammonia
  - odour
  - particulate matter (PM10 and PM2.5)

- End-of-pipe air treatment is essential to comply with these standards, other measures are not effective enough

Air scrubber…



Air scrubber…



Air scrubbers in livestock industry

- Both chemical and biological scrubbers (biotrickling filters) are applied since ~1995 in pig production in Northern Europe
- Currently about >10% of pig production in the Netherlands is depending on scrubbers
- Scrubbers are now introduced again in poultry industry because of their PM10 removal capacity

Acid scrubber: chemical process

- Dissolution:

NH_3 (g) → NH_3 (aq) → NH_4^+ (aq) + OH^- (aq)

- Dosing of sulphuric acid (low pH) drives equilibrium to right side

- Net reaction:

2 NH_3 (g) + H_2SO_4 → 2 NH_4^+ (aq) + SO_4^{2-} (aq)

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

Biological scrubber: bacterial conversions

- Nitrification:

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ *Dissociation / Dissolution*

$\downarrow$ 1.5 O_2 *Nitrosomonas Sp.*

$NO_2^- + H^+ + 2\ H_2O$

$\downarrow$ 0.5 O_2 *Nitrobacter Sp.*

$NO_3^- + H^+ + 2\ H_2O$

- Ammonium nitrite/nitrate solution is discharged (3 g N/L))
- Odour removal:
  - mixture of many compounds
  - oxidation to CO_2, H_2O and 'by-products'

Air scrubbers in animal production in NL

- Implementation since 1990's in NL, D and DK: mainly for ammonia abatement
- Commercially available as of-the-shelf product, 9 manufacturers in the Netherlands

- Estimated scrubber use in NL (2008), pigs only:
  - Acid scrubbers: 64 million m^3/hour (n>1000)
  - Biotrickling filters: 14 million m^3/hour (n>100)
  - in total: nationwide 10 – 15 % of all piggery air is treated

Development of supplier industry

- Mainly small specialized producers, limited R&D capacity, learning by doing
- skilled in hardware constructions, less understanding of biological principles
- Large engineering firms and suppliers of air scrubbers to (chemical) industry are absent
- Investment levels in livestock air cleaning are relatively low: per unit of product much air has to be cleaned

Example of a scrubber for application in poultry industry (2 wall design)

Removal performance of first generation air scrubbers in the Netherlands

- Overview of performances of ammonia scrubbers, measurements on 7 acid scrubbers and 9 biotrickling filters, operated on farm-scale
- Includes all published data on scrubbers in animal production in the NL between 1985 and 2004

In: Melse & Ogink, 2005, Trans. ASAE., 48 (6), 2303-2313.

Removal performance

NH_3: removal efficiency measured on farms

- Acid scrubbers:

  Mean and range: 96% (40 – 100)

- Biotrickling filters:

  Mean and range: 70% (-8 – 100)

Removal performance of current commercial scrubbers:
70 – 95%

Removal performance

Odor: removal efficiency measured on farms

- Acid scrubbers:

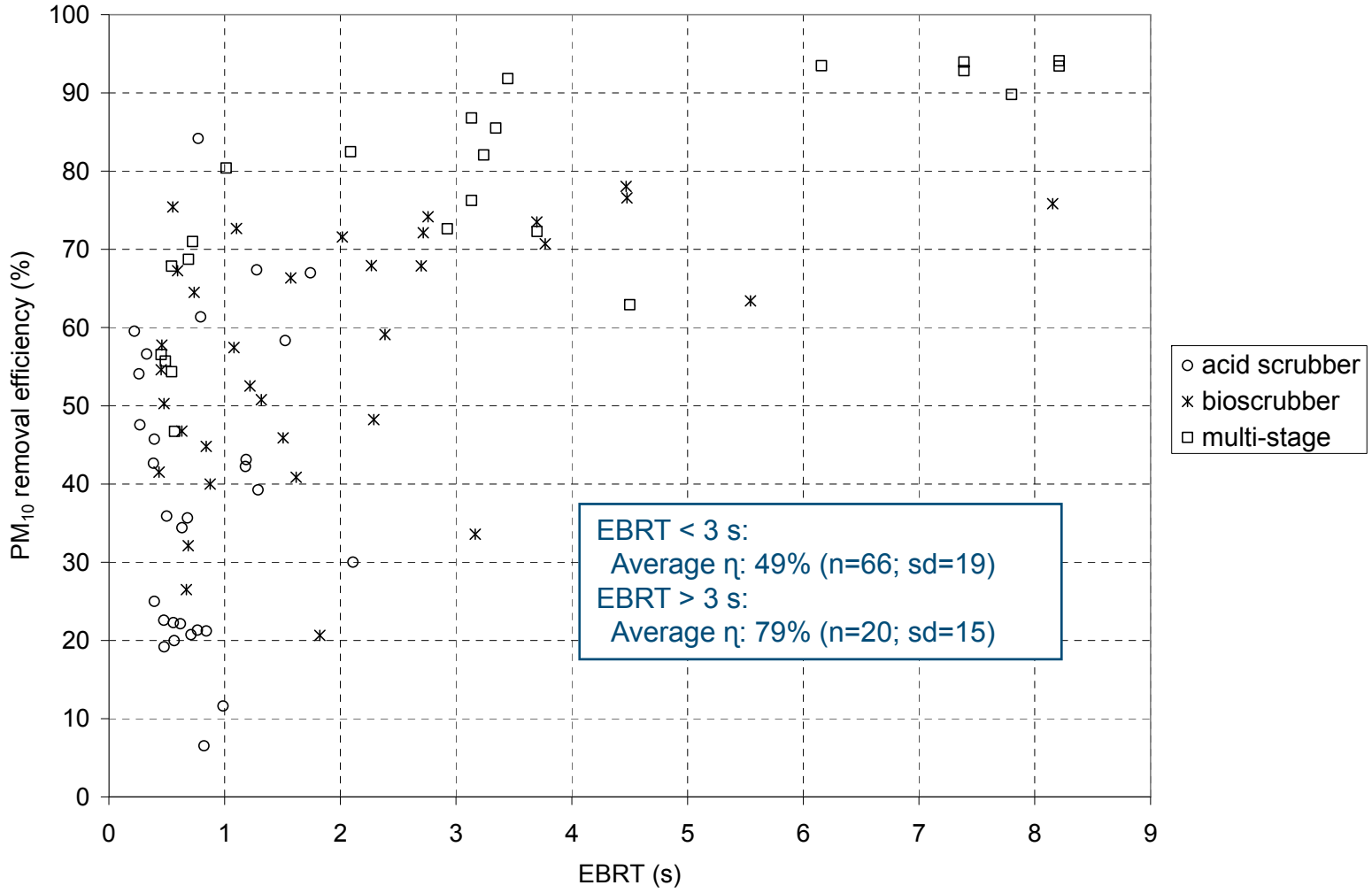
  Mean and range: 27% (3 – 51)

- Biotrickling filters:

  Mean and range: 51% (-29 – 87)

PM10 and PM2.5 removal: 30-75%

PM10 removal vs residence time



In: Melse, Hofschreuder & Ogink, 2012, Trans. ASABE

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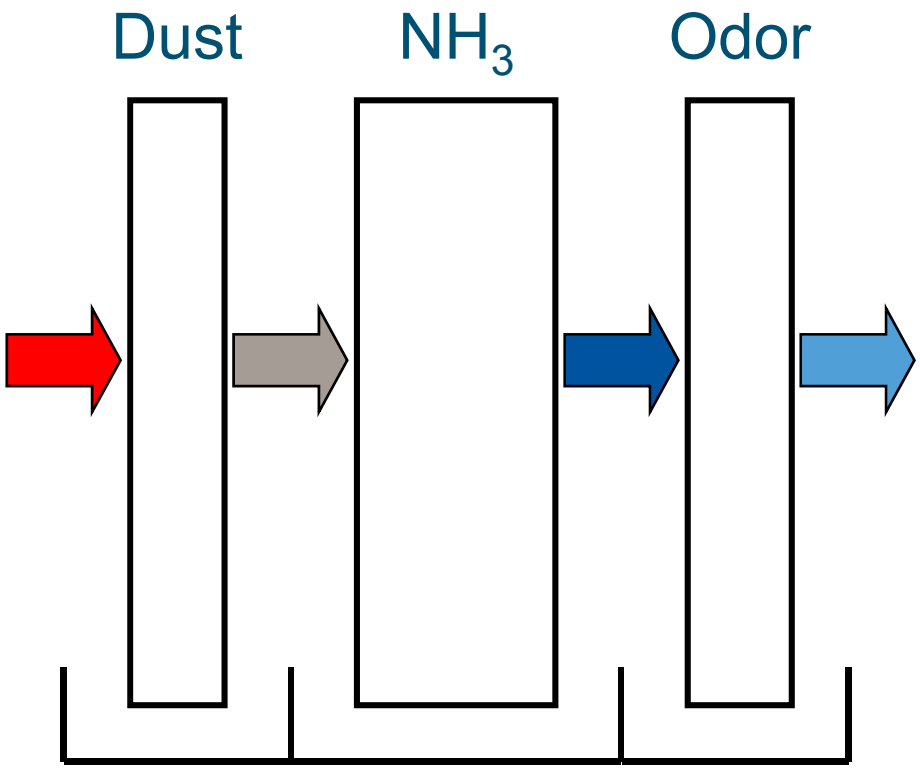
Development over last years: Combined or Multi-Pollutant air scrubbers

- Need for a new generation of scrubbers in intensive livestock production that remove at least 70% of NH3, odour and PM10

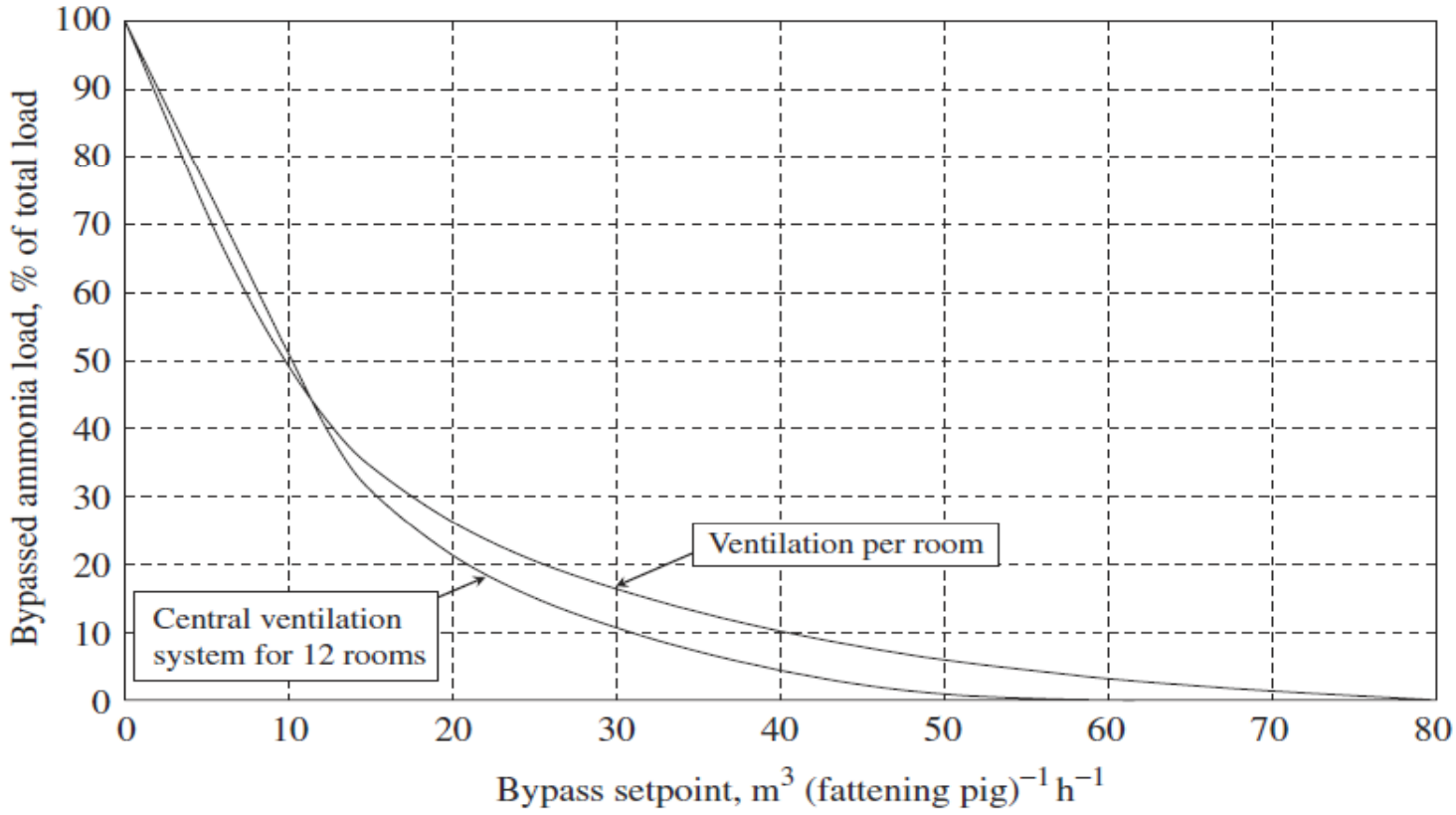
- Innovation required to improve performance, reliability and minimize costs

What do multi-pollutant scrubbers look like?



- Air flow is treated in steps:
  - Dust removal
  - Ammonia removal
  - Odour removal

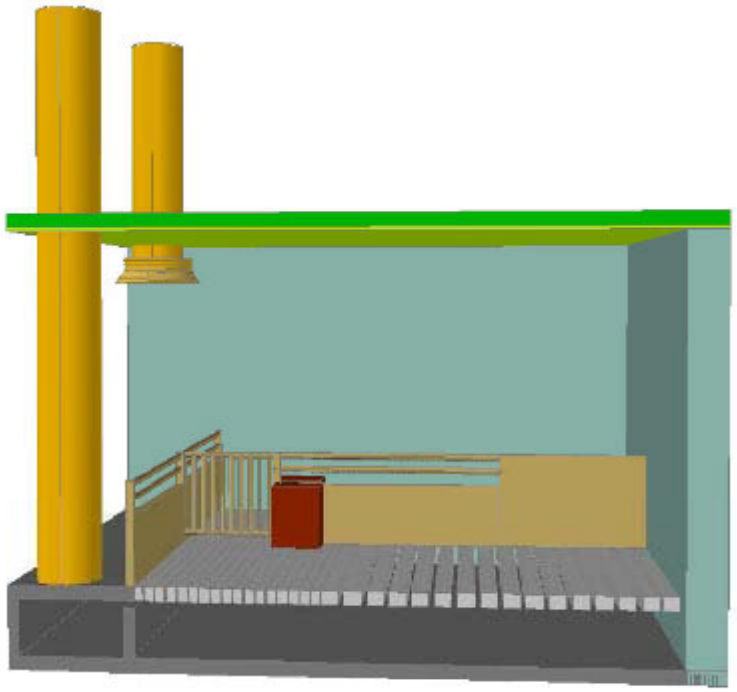
Partial cleaning of total air volume: a more effective strategy



R.W. Melse; A.V. van Wagenberg; J. Mosquera

Partial air cleaning of pit ventilation air: probably the best strategy

- Minimum ventilation (25%) implemented by pit ventilation, remaining air by room ventilation
- Only high ammonia pit air is treated by a scrubber
- Air quality is improved in pig pen and emissions are reduced



Poul Pedersen:
Aarhus University

Investment and operational costs

Important operational cost factors are:

- Energy use for ventilation (pressure drop)
- Energy use for pumps (liquid recirculation)
- Water discharge costs
- Acid use

Investment and operational costs: biological scrubbers

Commercial scrubbers 70% ammonia reduction

- Investment costs per m^3/h installed:

  € 0.48 (or € 37 per fattening pig place)

- Yearly operational costs per m^3/h installed :

  € 0.19 (or € 5.00 per produced pig)

Price level 2011, source: KWIN Livestock Research

Investment and operational costs: acid scrubber

Commercial acid scrubbers 70/90% ammonia reduction

- Investment costs per m^3/h installed:

  € 0.38-0.40 (or € 30-32 per fattening pig place)

- Yearly operational costs per m^3/h installed :

  € 0.14 – 0.17 (or € 3.70 – 4.70 per produced pig)

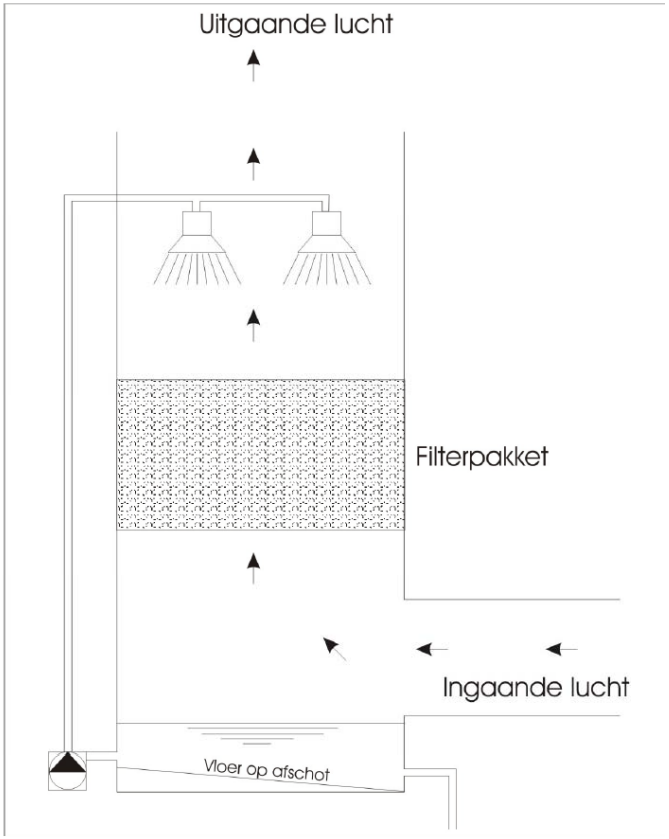
Price level 2011, source: KWIN Livestock Research

Implementation of scrubbers in regulations: ammonia emission factors in NL

- National list of housing systems with NH3-emission factors (kg NH3/year/animal) since 1995
- Standard factors for all housing systems, in all animal categories
- Factors are based on field measurements

- Description of essential system elements in leaflets
- Including end-of-pipe techniques: air scrubbers
- Regulatory list is used for farm permits

Example leaflet biotrickling filter 1998



Nummer systeem	**BWL 2008.01.V1**
Naam systeem	**Biologisch luchtwassysteem 70 % ammoniakemissiereductie**
Diercategorie	**Kraamzeugen, gespeende biggen, guste en dragende zeugen, dekberen en vleesvarkens (inclusief opfokberen en opfokzeugen)**
Systeembeschrijving van	**April 2009**
Vervangt	**Beschrijving BB 96.10.042 V1 van 29 oktober 1998**
Werkingsprincipe	De ammoniakemissie wordt beperkt door de ventilatielucht te behandelen in een biologisch luchtwassysteem. Bij het beschreven systeem bestaat de installatie uit een filterunit van het type tegenstroom. Via de ruimte onder het waspakket wordt de lucht door het waspakket geleid. In deze ruimte onder het waspakket vindt alvast enige bevochtiging van de lucht plaats. Verder wordt hier de lucht optimaal verdeeld over het gehele aanstroomoppervlak van de wassectie. De wassectie bestaat uit een kolom met vulmateriaal dat continu wordt bevochtigd met wasvloeistof. Bij passage van de ventilatielucht door het luchtwassysteem wordt de ammoniak opgevangen in de wasvloeistof, waarna de gereinigde ventilatielucht het systeem verlaat. Bacteriën die zich op het vulmateriaal en in de wasvloeistof bevinden zetten de ammoniak om in nitriet en/of nitraat, waarna deze stoffen met het spuiwater worden afgevoerd.

DE TECHNISCHE UITVOERING VAN HET SYSTEEM

	Onderdeel	Uitvoeringseis
1	Ventilatie	aanvoer ventilatielucht naar luchtwassysteem, zie hiervoor de checklist ventilatie bij luchtwassysteem uit het technisch informatiedocument 'Luchtwassystemen voor de veehouderij'
2a	Dimensionering luchtwassysteem	wasser van het type tegenstroom
2b		opgebouwd uit een kolom kunststof filtermateriaal (contactoppervlak filtermateriaal is 243 m^2 / m^3) met een hoogte van minimaal 0,75 meter en maximaal 1,35 meter
2c		capaciteit maximaal 5.000 m^3 lucht per uur per m^3 volume
2d		aan te tonen met dimensioneringsplan bij aanvraag vergunning, waaruit onder meer de relatie met het aantal dieren per diercategorie blijkt (maximale ventilatie)
3a	Registratie	continue registratie van het aantal draaiuren van de circulatiepomp met behulp van een urenteller

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Verification of farm operation of air scrubbers in the Netherlands

Current approach:

- Inspection as built
- On site farm inspection (1-2 year)
- Sampling of scrubber liquid (1-2 year)
- Registration of pumping hours in logbooks
- Registration of water discharge in logbooks

In practice this system is not working properly

Implementation of scrubbers in regulations: Denmark and Germany

- Denmark: development over recent years of Best Available Technology (BAT) list, with ammonia emission factors

- Germany: implementation in regulations differs between regions, in a number of regions use is made of DLG-certificates for scrubbers

Field inventory of scrubber use: paper and practice

- Increase of complaints on odour nuisance in regions with pig producers that use air scrubbers (NL)
- Field inventory 2010, NL: substantial part of scrubbers did not comply with regulatory demands , in some (incidental) cases scrubbers were not implemented
- Field inventory 2010, DK: substantial part of scrubbers did not comply with regulatory demands

New verification approach scrubbers

Continuous logging of essential parameters (electronic monitoring):

- pH of recirculation water (pH sensor)
- Conductivity of recirculation water
- Pressure drop over packing material
- Operational hours of essential components
- Air and liquid flows

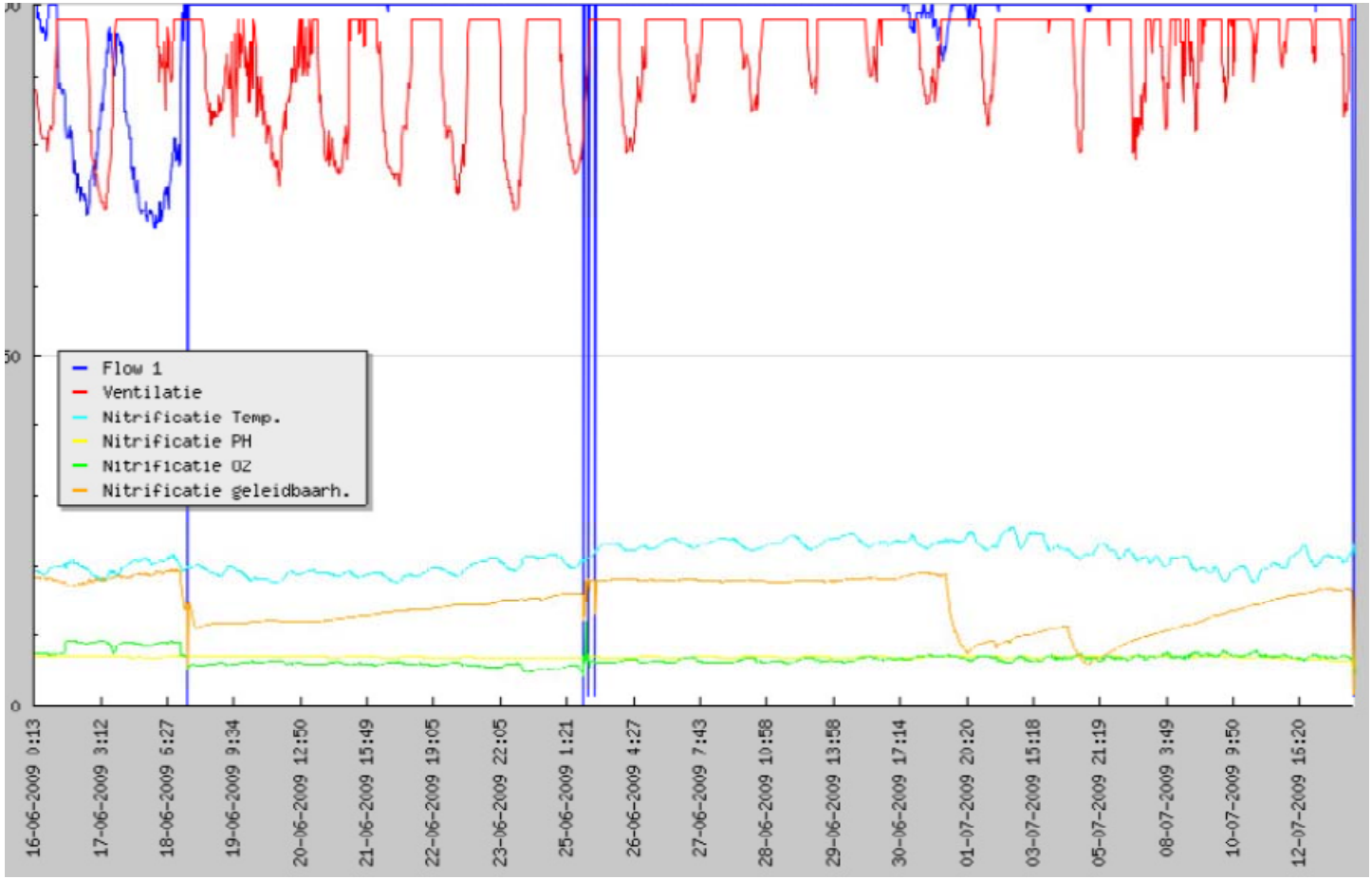
Storing all essential parameters in secured database

Database at any time accessible for stakeholders

From: incidental verification

To: continuous registration and logging

Example: continous parameter registration



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Benefits new verification approach

Benefits monitoring and logging:

- Increased performance verification
- Improved operational stability of scrubbers

Cost efficiency for all stakeholders involved:

- Inspection (restricting site visits)
- Farmer (saving analysis costs, energy use)
- Supplier (improved service of installation)

Test pilot in 2009-2012, introduction in near future (2013).

Pros and cons of air cleaning technology in pig production

- Air cleaners are capable of reaching high removal percentages of pollutants
- Air treatment technology enabled upscaling of pig farms in high density areas

But

- Indications that air quality in pens deteriorate (>ppm NH3) as a result of minimizing ventilation volumes
- Public confidence in pig producers is under pressure as a result of improper implementation and use of air cleaners

International evaluation of air cleaning technology in livestock production: VERA

- Joint initiative of authorities in Denmark, Germany and the Netherlands: development of test protocols for air cleaners and other low emission housing systems

- Objective: recognition of test results across borders, reducing test costs for suppliers

VERA Verification of Environmental Technologies for Agricultural Production

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Conclusions and outlook

- Air treatment technology can play an essential role in ensuring future of intensive livestock industry in high density areas in Europe
- Improvement of on farm verification schemes required to regain public confidence
- Attention is required to counteract negative effects on room air quality
- Effectiveness and cost level of air cleaning can be further improved by partial air cleaning, and the combination of pit ventilation and air cleaning

Thank you for your attention

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