Airborne transmission of Avian Influenza between poultry farms:

“what do we know?”
“what can we do?”

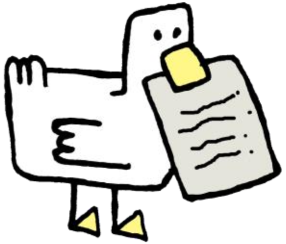
Mattias Delpont
PhD, dipl. ECPVS

SIPA VIII Simposĺo Scientifico, Forlì,
24th November 2023

Allegory of air, Jan Van Kessel, 1661

INRAE
école nationale vétérinaire toulouse
Chaire de Biosécurité & Santé Aviaires

Foreword(s)



How ventilation can influence biosecurity and which solutions could be implemented?

Avian Influenza in high-density regions

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Foreword(s)

Virology

On-farm disease management

Epidemiology

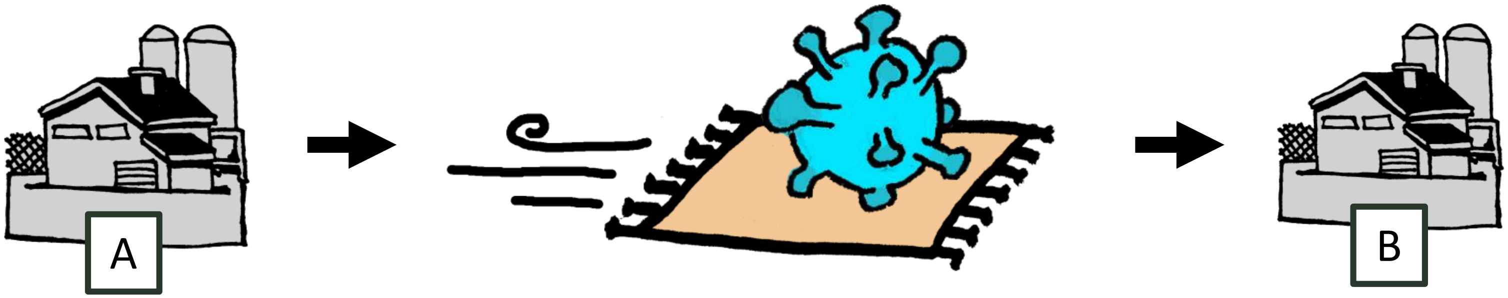
micro

macro

Questions and keys aspects of the presentation

HPAI needs **vehicles** for airborne transmission

1 What are these vehicles?



2 How are they **emitted**?

3 What **happens** to these vehicles and the viruses **during** airborne **transport**?

4 How do they **enter** the poultry **barns** (and the poultry…)?

Which biosecurity practices for each step?

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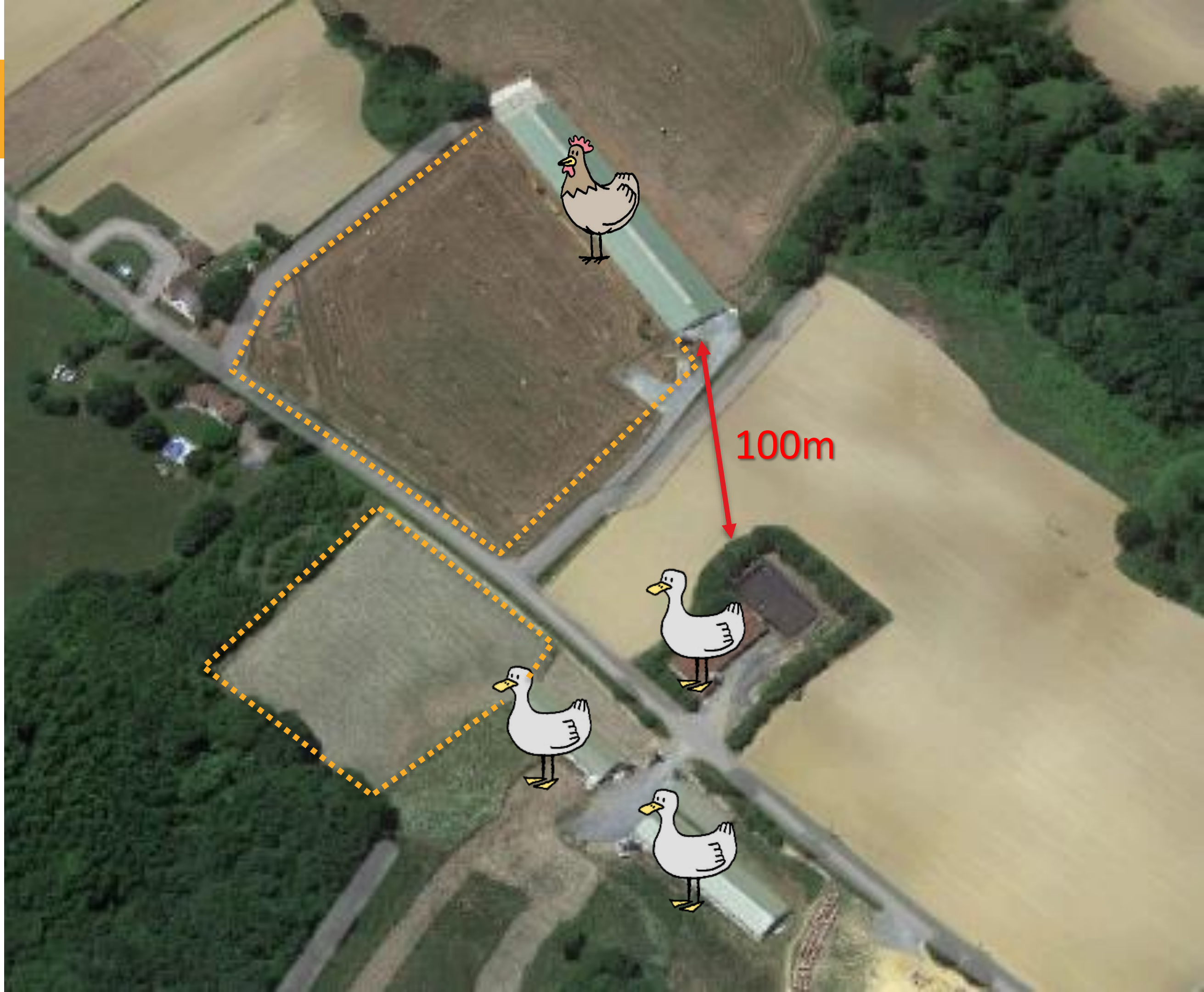
Introduction

Southwest France,
May 2023



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Introduction : **Farm density and AI**, a long story

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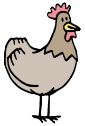


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Risk factors associated with highly pathogenic avian influenza subtype H5N8 outbreaks on broiler duck farms in South Korea


W-H Kim [1], J-U An [1], J Kim [1], O-K Moon [2], S

Zoonoses Public Health. 2007;54(9-10):337-43. doi: 10.1111/j.1863-2378.2007.01074.x.

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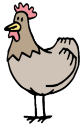

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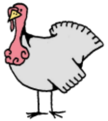

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“farm location in an existing control zone”

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“Presence of any poultry farms located within 500 m of the farm" (OR = 6.30)”

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“Direct distance to the nearest case farm' (0-500 m, OR = 8.6)”

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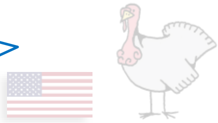

“proximity to other turkey operations” (OR = 46.14)”

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<u>What makes closeness a cause of infection?</u>

People? Shared equipment? Insects?
Rodents? Wild birds? Air?

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What is in the air?

What is in the air? **Words and definitions**

- **Particulate Matter** (PM) = **Aerosols** = atmospheric aerosol particles. Mixture of microscopic liquid and solid particles suspended in the air
- **Bioaerosol** = viable and non-viable biological particles suspended in the air
- **Droplet** (≥ 5 µm OR ≥ 100 µm, depending on authors…)
- **Respiratory droplet** = droplet derived from the respiratory tract
- **Droplet nuclei** = microscopic aerosol particles consisting in the residual solid cores of evaporated respiratory particles
- **Dust** = fine particles of solid matter (settled or airborne); they sediment under gravity force

What is in the air? **Words and definitions**

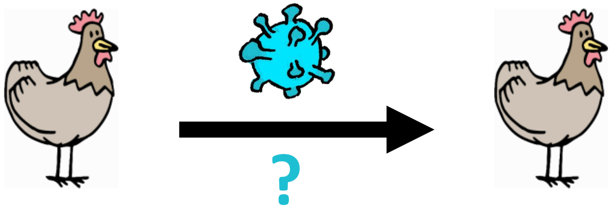
- **Respirable** and **non-respirable particles**
  - Inhalable ≤ 100 µm
  - Thoracic ≤ 10 µm
  - Respirable ≤ 5 µm

Species-dependent

- **$PM_{2.5}$ and PM_{10}**
  - PM_{10} ≤ 10 µm
  - $PM_{2.5}$ ≤ 2.5 µm

What is in the air? **Particle types and origins**

- Litter
- Droplets
- Feed
- Skin, dander
- Feathers
- Fungi (spores)
- Faeces
- Insects (or insect parts)



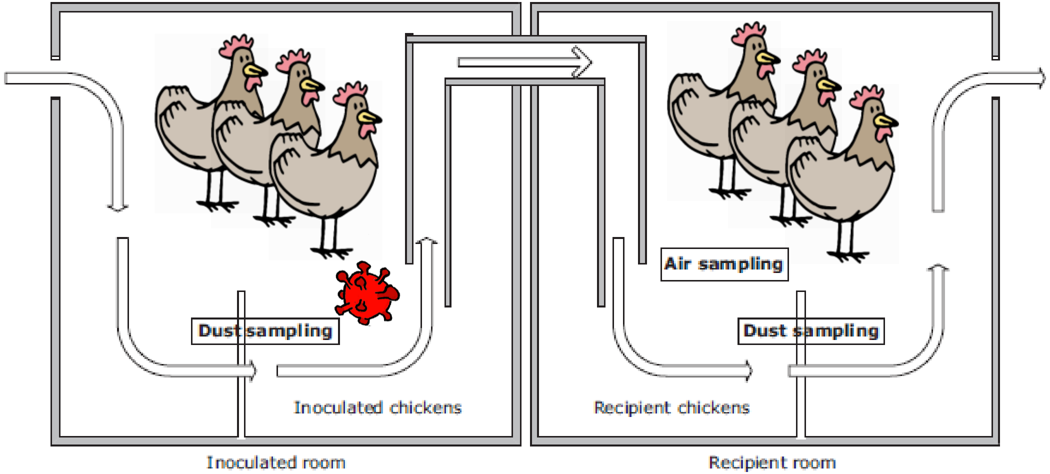
Animal to animal airborne transmission

“What do we know?”

Dustborne infection by HPAI

Spekreise et al, 2012

- Laboratory conditions
- Chickens in first room inoculated with H5N1
- aerosol + dust sampling



✓ Airborne transmission of AI
✓ Airborne and dustborne infectious AIV

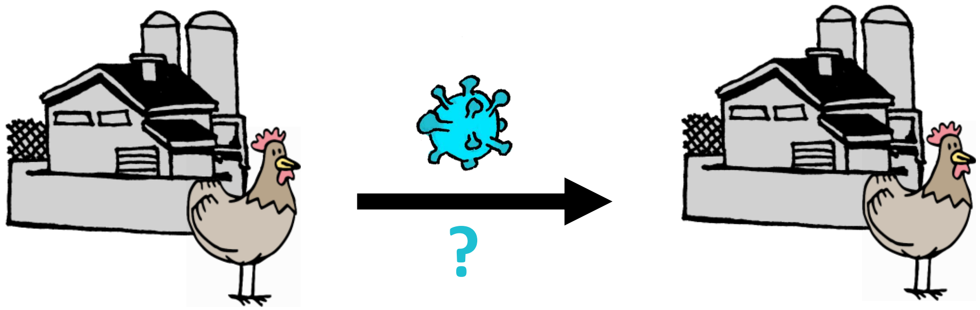
The role of AI strain for airborne infection

J Infect Dis. 2009 Mar 15;199(6):858-65. doi: 10.1086/597073.

Transmission of influenza virus via aerosols and fomites in the guinea pig model

Samira Mubareka [1], Anice C Lowen, John Steel, Allan L Coates, Adolfo García-Sastre, Peter Palese

- ✓ Different **strains** of AIV =
  different capacity to infect **via aerosol transmission**

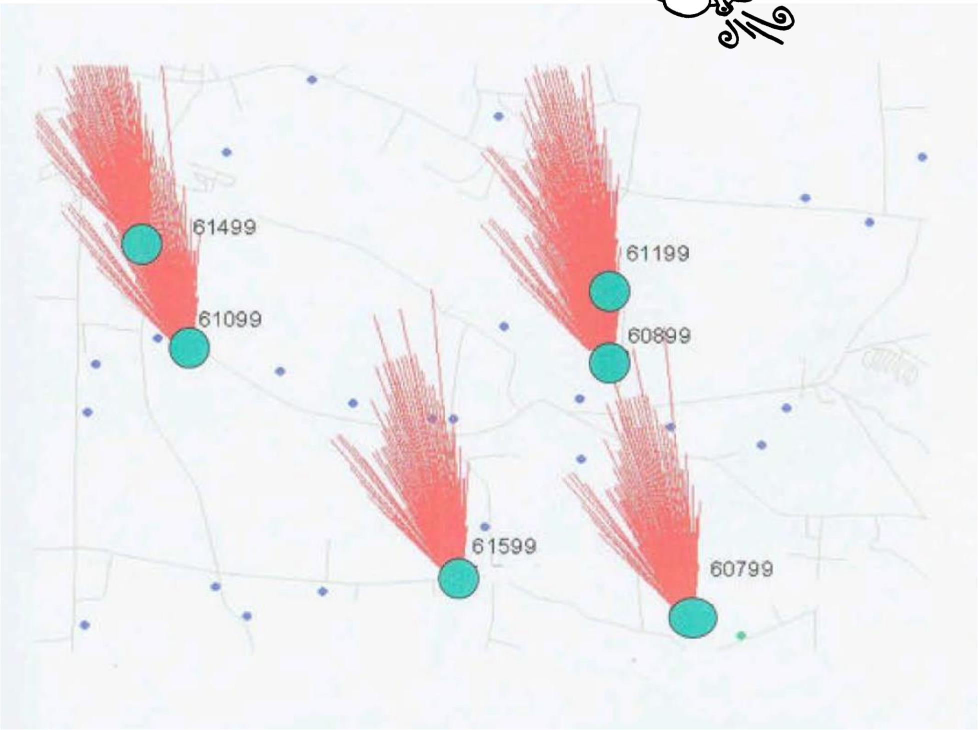


<u>Farm to farm</u> airborne transmission.

"What do we know?"

Documenting airborne farm to farm transmission

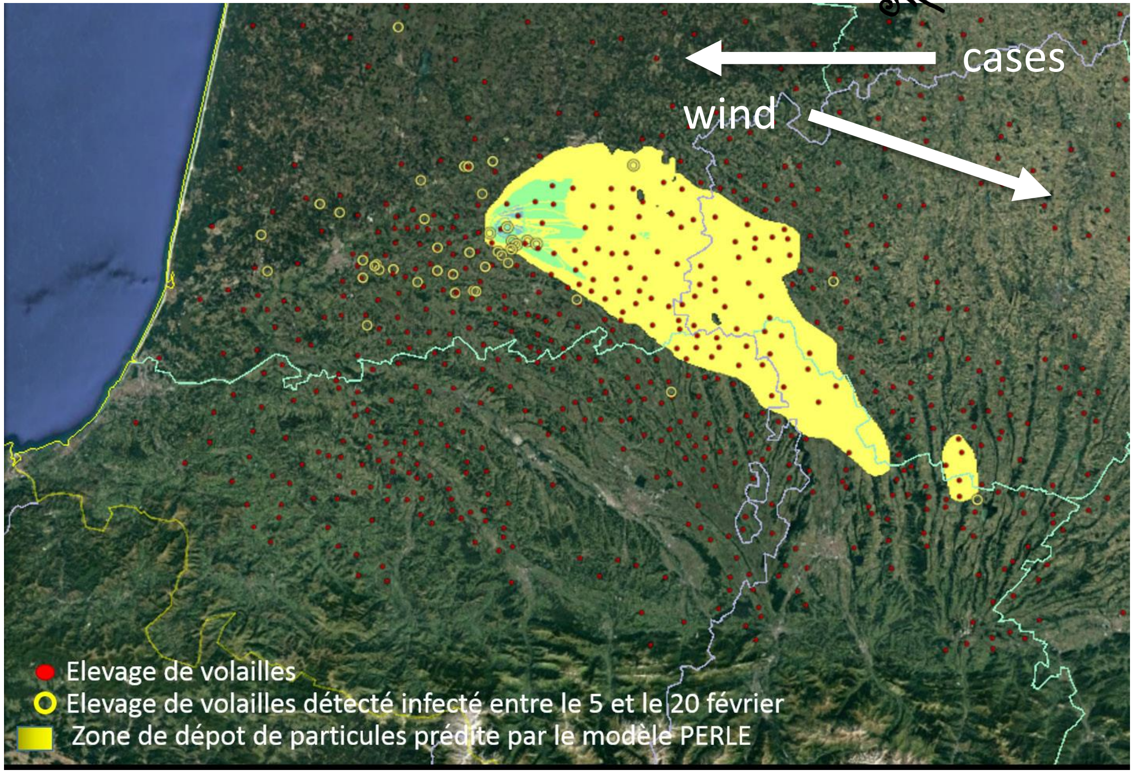
- Infectious Laryngotracheitis (USA)
- Case farms were **9.9 more likely located within the wind vector of a clinical flock** during infectious period
- House ventilation system and house orientation were not retained



Johnson et al, 2005

Documenting airborne farm to farm transmission

- HPAI, France, 2017
- Peak of cases after a (major) storm
- Outbreak progression and particle dispersion (modeled) were in <u>opposite directions</u>…



Guinat et al, 2019

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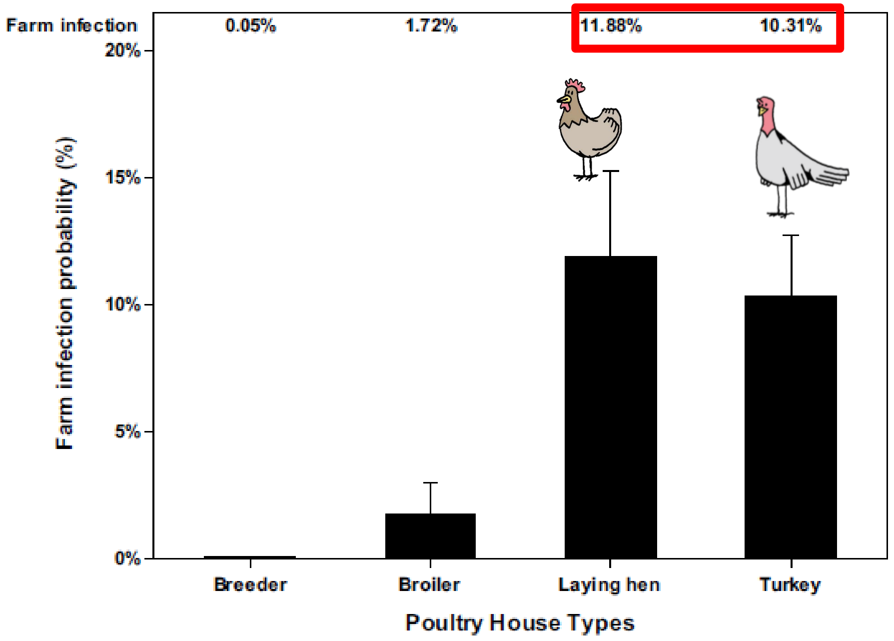
Documenting airborne farm to farm transmission

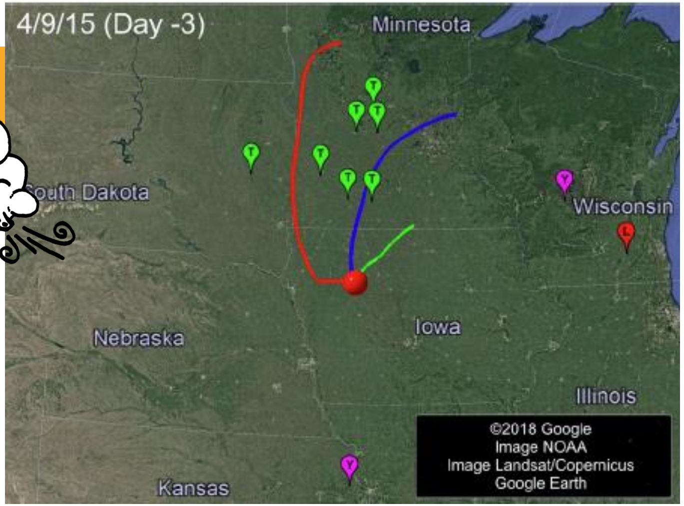
- HPAI, USA, 2022 (spring-summer)
- Modelling $PM_{2.5}$ poultry litter dust particles, long distance



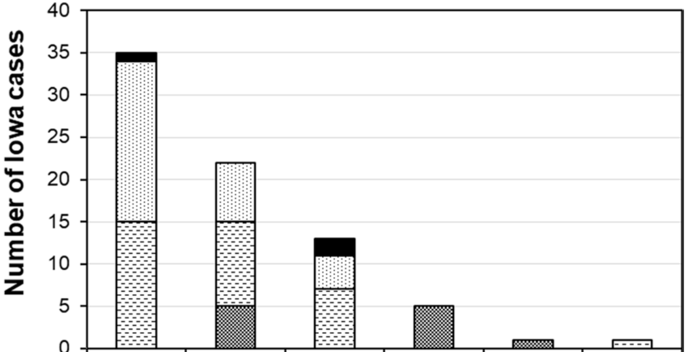
(a)

Nguyen et al, 2023

Documenting airborne farm to farm transmission



- HPAI, USA, 2015
- Majority of cases might have received airborne virus, carried by fine particulate matter



Risk category	Turkey	Layer	Pullets	Backyard	Breeder	Hatchery
High (>50%)	1	0	2	0	0	0
Medium (10-50%)	19	7	4	0	0	0
Low (1-10%)	15	10	7	0	0	1
Extremely low (<1%)	0	5	0	5	1	0

Zhao et al, 2018

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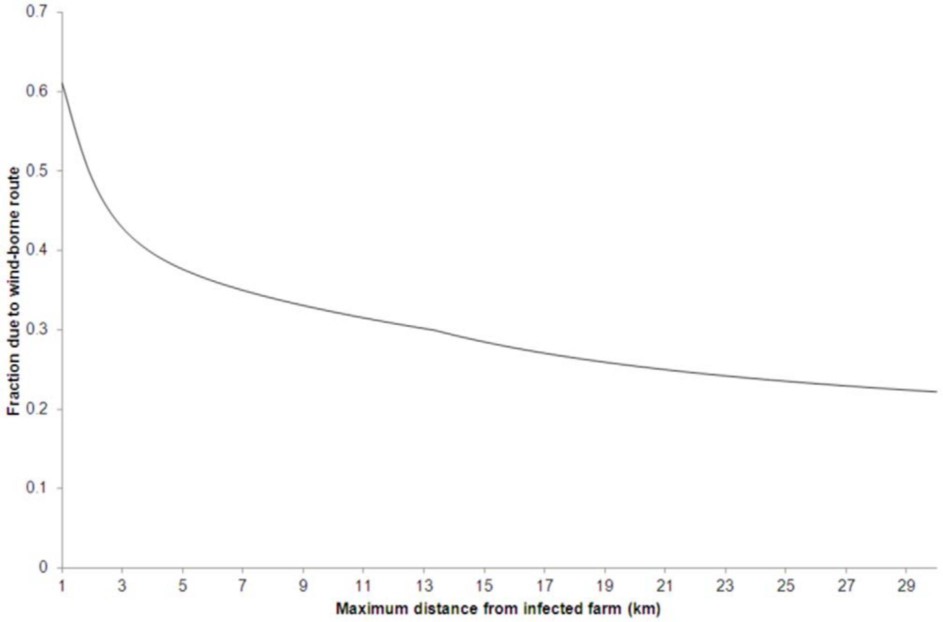
Documenting airborne farm to farm transmission

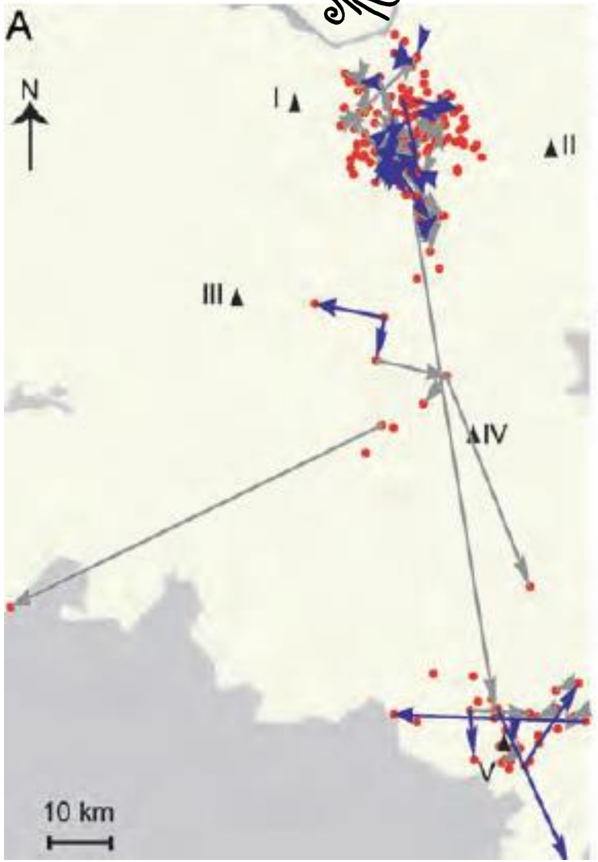
- HPAI, The Netherlands, 2003
- 24% of the transmissions over distances up to 25 km.



Ssematimba et al, 2012

Documenting airborne farm to farm transmission

- HPAI, The Netherlands, 2003
- Wind data + genetic data
- Contribution of possible wind-mediated mechanism on total of cases = 18%

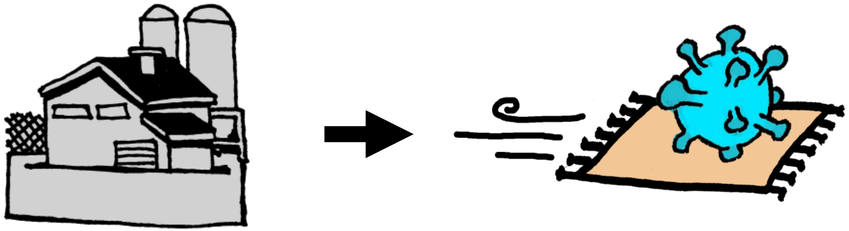


Blue arrows: transmission that coincide with wind direction

Ypma et al, 2013

Documenting farm to farm transmission

- Wrap-up!
  - Airborne farm infection **possible**
  - Airborne farm infection **not always easy to prove**
  - Airborne farm infection **more efficient with wind and over short distances**
  - **Variable contribution** of airborne farms infections during epidemics



Emission of aerosols and pathogens

“What do we know?”

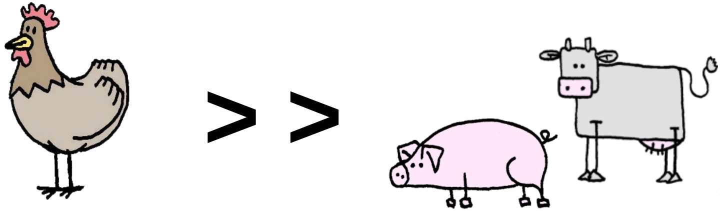
Poultry: a hotspot for **PM production**

TABLE 2. Concentrations of airborne microorganisms and dust in livestock production systems

Animal	Bacteria[a] log CFU m^{-3}	Fungi[a] log CFU m^{-3}	Inhalable Dust[b] mg m^{-3}	Respirable Dust[b] mg m^{-3}	PM_{10}[c] mg m^{-3}	$PM_{2.5}$[c] mg m^{-3}
Broiler	6.4	4–5	3.8–10.4	0.42–1.14	0.9–2.4	0.04–0.09
Layer	4–5	3–4	1.0–8.8	0.03–1.26	5.9–6.1	0.25–0.29
Pig	5.1	3.7	0.6–5.1	0.09–0.46	0.2–2.0	0.01–0.07
Cattle	4.3	3.8	0.1–1.2	0.03–0.17	0.1	0.01

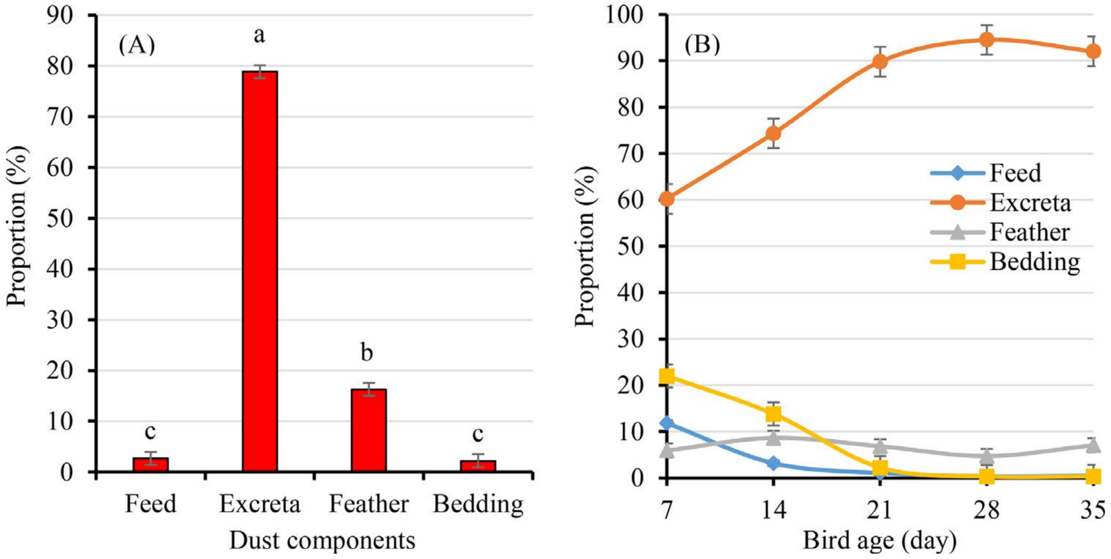
[a]Data from Seedorf et al. (1998). [b]Data from Taikai et al.(1998). [c]Data from Lai et al. (2010).

Zhao et al, 2014



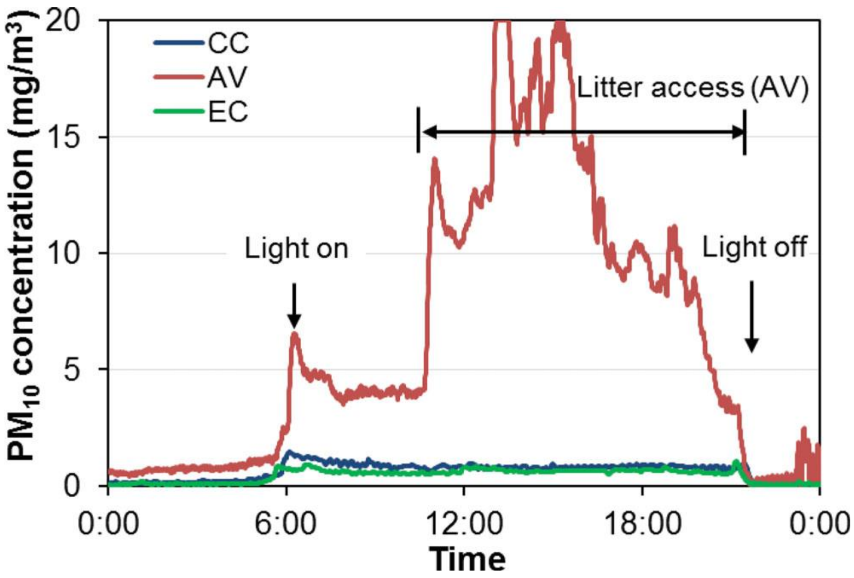
Dust composition

- Broiler chicken dust (Ahaduzzaman et al, 2021)
  - 60% **faeces** at D7
  - 95% **faeces** at D35
  - **Feathers** around 10%



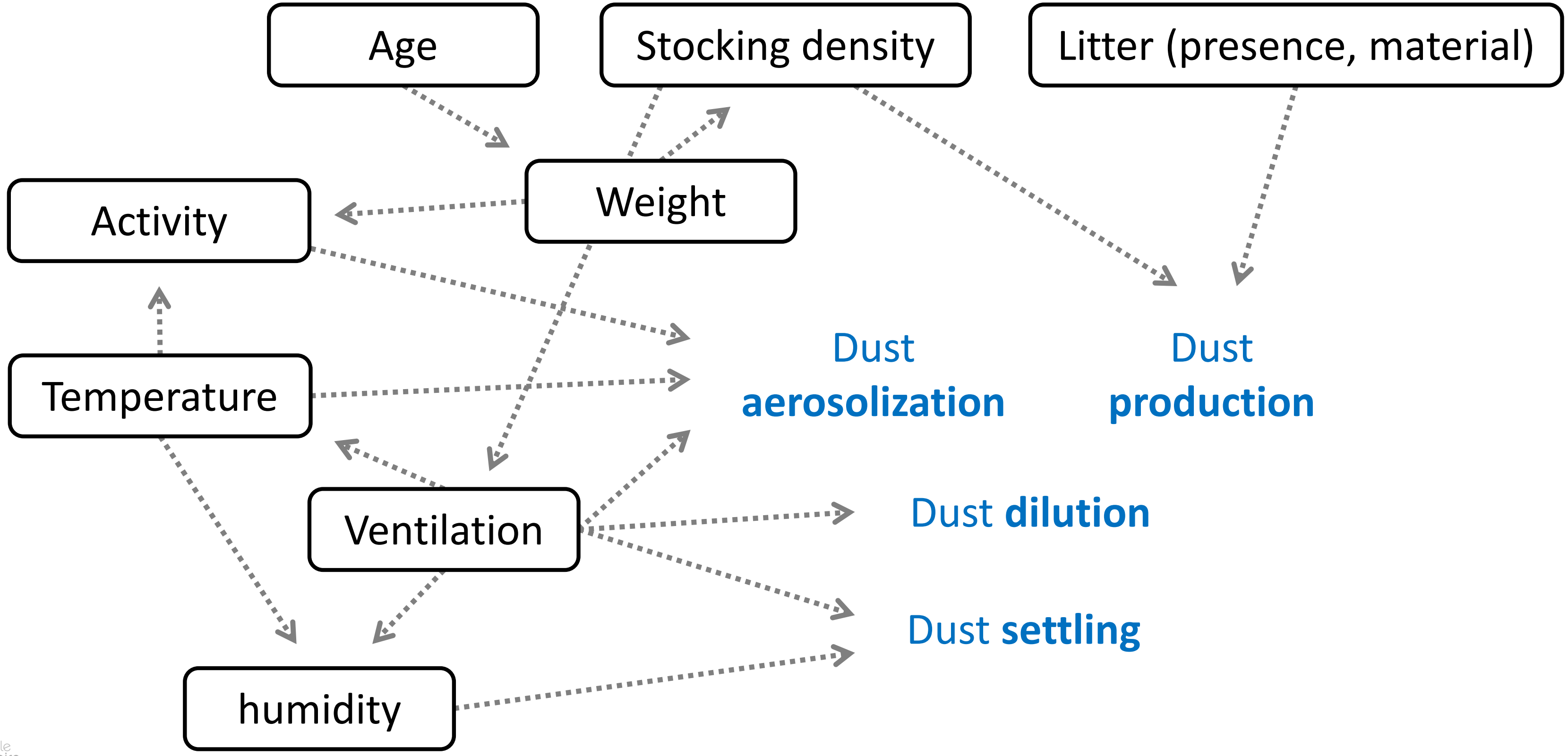
PM emission from poultry houses

- High PM for **high** hen **activity**
- High PM for **low temperatures**
- High PM for **low ventilation rate**



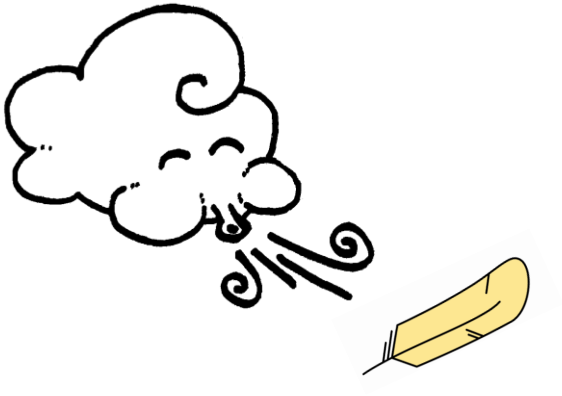
Zhao et al, 2015

Many factors for PM/dust production



Zhao et al, 2014 Bist et al, 2022

Emissions **from outside** the poultry barn

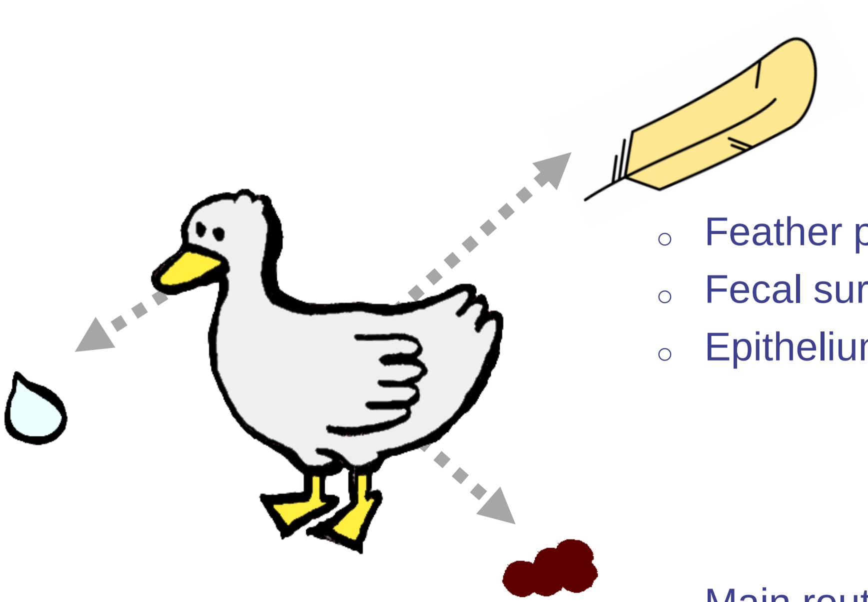


Aerosolization by the **wind**
- Any particle on the floor
- Internal biosecurity

Manure
- Fecal → pathogens ++
- Uncovered storage
- Spreading

IAV: excretion

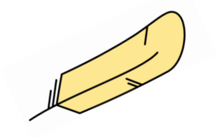
Amount of virus depends on species, viral strain, etc.



- Feather pulp
- Fecal surface contamination
- Epithelium of growing feathers!

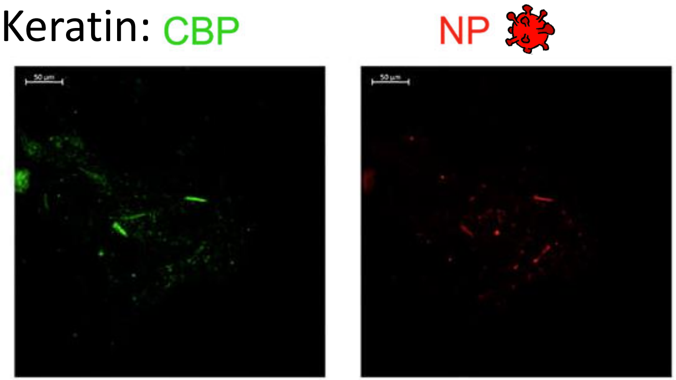
- Main route
- Litter/faeces management

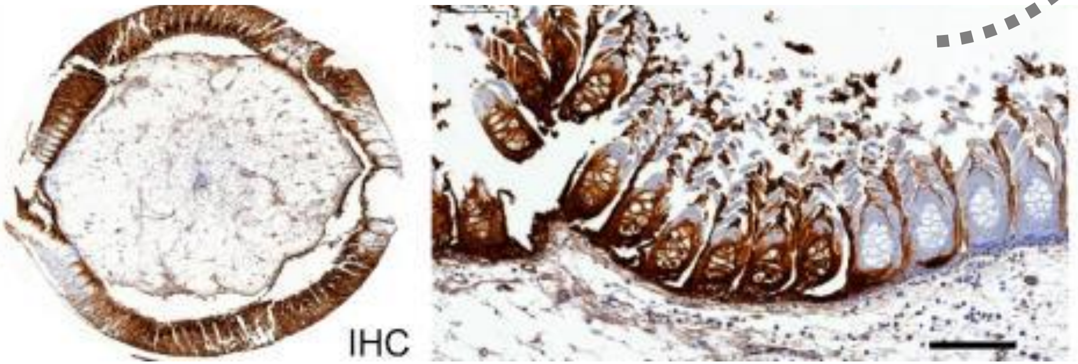
IAV: feathers and excretion



Gaide, Filaire et al, 2023

HPAI is produced and emitted from **feathers**, after desquamation (+++ in ducks) and these (still infectious) particles become **airborne**





Aerosols

IAV: infectivity in dust and aerosols

Outbreak farms : HPAI infectivity in dust and aerosols particles (>1µm)

Infectivity

Table 2. Viral isolation assays on chicken embryonated eggs performed on 5 of the 63 poultry houses in a study to detect highly pathogenic avian influenza A(H5N8) virus on poultry farms, France, December 2020–April 2021*

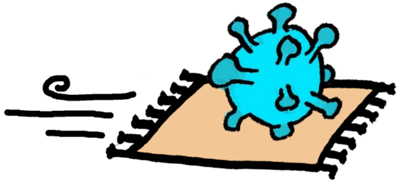
	House 11		House 26		House 29		House 30		House 34	
Sample type†	Ct	VI	Ct	VI	Ct	VI	Ct	VI	Ct	VI
Tracheal swab	25	+	20.7	+	21.9	+	18.9	+	20	+
Dust wipe, feeders	25.8	–	25.1	–	27.4	+	29.5	+	24.2	+
Dust wipe, walls	27.5	+	25.5	–	30.1	+	28.3	+	23	+
Coriolis	32	–	33.6	–	27.8	–	25.8	+	26.9	+
NIOSH BC251										
Fraction 1	34	–	33.6	–	27.8	–	25.8	+	23.7	+
Fraction 2	–	ND	36	–	32.4	–	33.1	–	18.6	+
Fraction 3	–	ND	–	ND	36.3	–	–	ND	–	ND

*Ct, cycle threshold; ND, not done; VI, virus isolation; +, positive; –, negative.
†Each farm or building was sampled by using 4 pools of 5 tracheal swab samples, 2 wipe samples (1 from feeders, 1 from walls), and on 19 farms, 1 air sample from each of the 2 aerosol collection devices, the Coriolis Compact (Bertin Instruments, https://www.bertin-instruments.com) and the NIOSH BC 251, developed by the National Institute for Occupational Safety and Health (https://www.cdc.gov/niosh). NIOSH BC 251 sampling device has 3 fractions for different particle sizes; fraction 1 for >4 µm, fraction 2 for 1–4 µm, and fraction 3 for <1 µm.

Filaire et al, 2022

Feather in dust, but also …

Proximity to roads for airborne transmission …



Transport and stability of pathogens on aerosols.

“What do we know?”

Stability of PM

- **Physical decay**: Gravitational sedimentation | Impaction | Electrostatic precipitation

  - ➢ Dominant mechanism depends on particle size (Zhao et al, 2014)
  - ➢ Lowest deposition rate between 0.1 and 1 µm (Lai, 2002)
  - ➢ Air speed increase → deposition of particles 0.5 – 10 µm (Thatcher et al, 2002)

Wet aerosols:

- Big particles → settle very quickly
- Small particles → quick evaporation and further dispersion

Dry aerosols (feces, litter)

- Further spread than wet sources
- Further spread when small

Stability of airborne microorganisms

- **Biological decay**:

  - **UV-C (100-280 nm)** is the more germicidal, specifically 250-270 nm
    - Absorbed by genetic material,
    - Pyrimidine → inhibits replication and function.
    - RNA more resistant.
  - **Oxydation:** Viruses are less sensitive
  - O_3 → Damages viral nucleic acids + alters polypeptide chain of viral protein coat
  - **Humidity** decrease → inactivation of IAV (Sedlmaier et al, 2009)
  - **Dust / organic matter** → protect microorganisms (exposition, fluctuations):

Dungan, 2010

Deposition or airborne microorganisms

- **Meteorological** factors
  - **Wind velocity**
    - High wind-speed / shorter distances → less time to become inactivated
  - **Relative humidity** : affects settling velocity (via density and diameter)
  - **Temperature**
  - **Precipitation** → Wash-out by rain drops

  - PM ≥ 5 µm : gravitationnal settling and impaction
  - PM ≥ 25 µm : removal by raindrops

Dungan, 2010

IAV airborne stability

Review > J Infect. 2008 Nov;57(5):361-73. doi: 10.1016/j.jinf.2008.08.013. Epub 2008 Oct 9.

Inactivation of influenza A viruses in the environment and modes of transmission: a critical review

Thomas P Weber [1], Nikolaos I Stilianakis

Airborne inactivation

- Low RH & low T°
- High RH & medium T°
- ...

Not always straightforward

Table 2. Estimated daily inactivation rates of influenza A viruses in aerosols

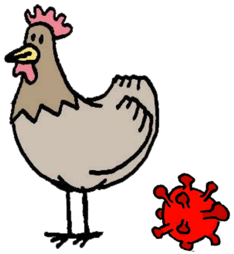
RH %	Temperature, °C	Inactivation rate (day^{-1})
50		96–312
70		62–166
20		≈20
80–90		≈400
23–25	7.0–8.0	0.34
51	7.0–8.0	1.25
82	7.0–8.0	3.6
20–22	20.5–24.0	1.22
50–51	20.5–24.0	13.9
81	20.5–24.0	19
20	32.0	4.1
49–50	32.0	17.3
81	32.0	60.7
50, 65, 80	21–24	16.85
20, 35	21–24	1.58–2.05

IAV airborne stability

> Can J Comp Med. 1972 Jan;36(1):9-11.

Influenza A of human, swine, equine and avian origin: comparison of survival in aerosol form

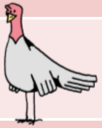
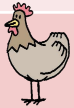
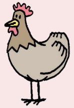
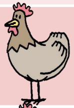
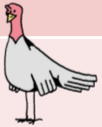
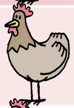
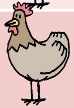
C A Mitchell, L F Guerin



Strains of avian/equine origin
→ more resistant to decay

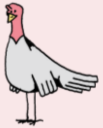
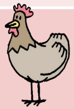
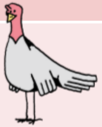
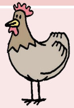
Outbreak samples

AIV identification in/around outbreaks in **aerosols**

ref	Virus	species	Airborne - Indoors – infectious	Airborne – indoors - vRNA	Airborne - Outside - Infectious	Airborne - Outside - vRNA
James, 2023	H5N1 2.3.4.4b (UK)		+	+	≤1m (1/4)	≤10m (3/4)
James, 2023	H5N1 2.3.4.4b (UK)		+	+	(0/3)	≤1m (1/3)
James, 2023	H5N1 2.3.4.4b (UK)		-	+	(0/3)	(0/3)
Scoizec, 2018	H5N8 2.3.4.4 (FR)	 	Not tested	+	Not tested	≤5m (4/4) [50-110](3/5)
Torremorell, 2016	H5N2 2.3.4.4 (USA)		+	+	≤70m (larger than 2.1 μm)	≤150m
Jonges, 2015	LPAI (NL)	 		+	-	≤60m
Li, 2016	HN9 (CN)		+	+	-	≤1,500m

AIV identification in/around outbreaks in **dust**

Outbreak samples

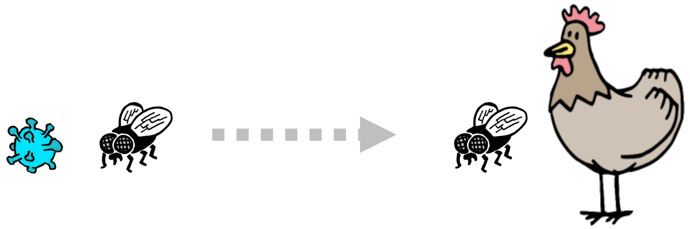
ref	Virus	species	Dust - Indoors – infectious	Dust – indoors - vRNA	Dust -Outside distance - Infectious	Dust - Outside distance - vRNA
James, 2023 (UK)	H5N1 2.3.4.4b		+	+	Outside vent	Outside vent (feathers 10m)
James, 2023 (UK)	H5N1 2.3.4.4b		-	+	-	Outside vent(feathers 50m)
James, 2023 (UK)	H5N1 2.3.4.4b		-	-	-	Outside vent
Torremorel, 2016	H5N2 2.3.4.4	 	-	+	-	≤1000m

The role of flies in the transmission of HPAI

Experimental infection

Wanaratana et al, 2013

- HPAI H5N1
- Flies: consumption of infected food
- Chickens: consumption of flies



Successfull infection with infected flies

Table 1. MDT and mortality of chickens inoculated with the homogenate of HPAI-H5N1 virus contaminated houseflies (n = 10).

	Number of chicken deaths each day							
Group[A]	1 DPI	2 DPI	3 DPI	4 DPI	5 DPI	6 DPI	7 DPI	MDT
1	0	0	0	0	0	0	0	0
2	0	1	2	3	2	1	1	4.3
3	0	0	1	0	4	2	3	5.6

control

Fed exposed flies

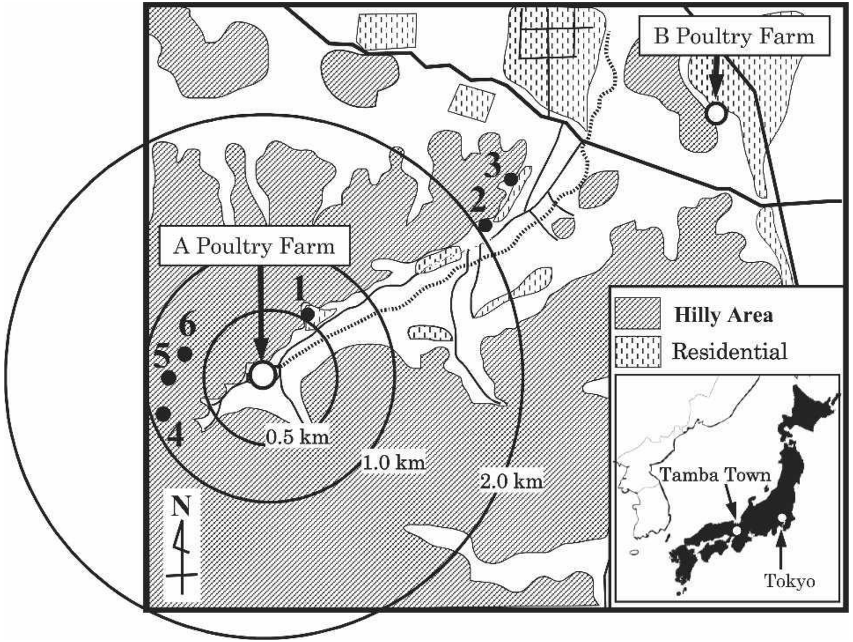
The role of flies in the transmission of HPAI

Outbreak samples

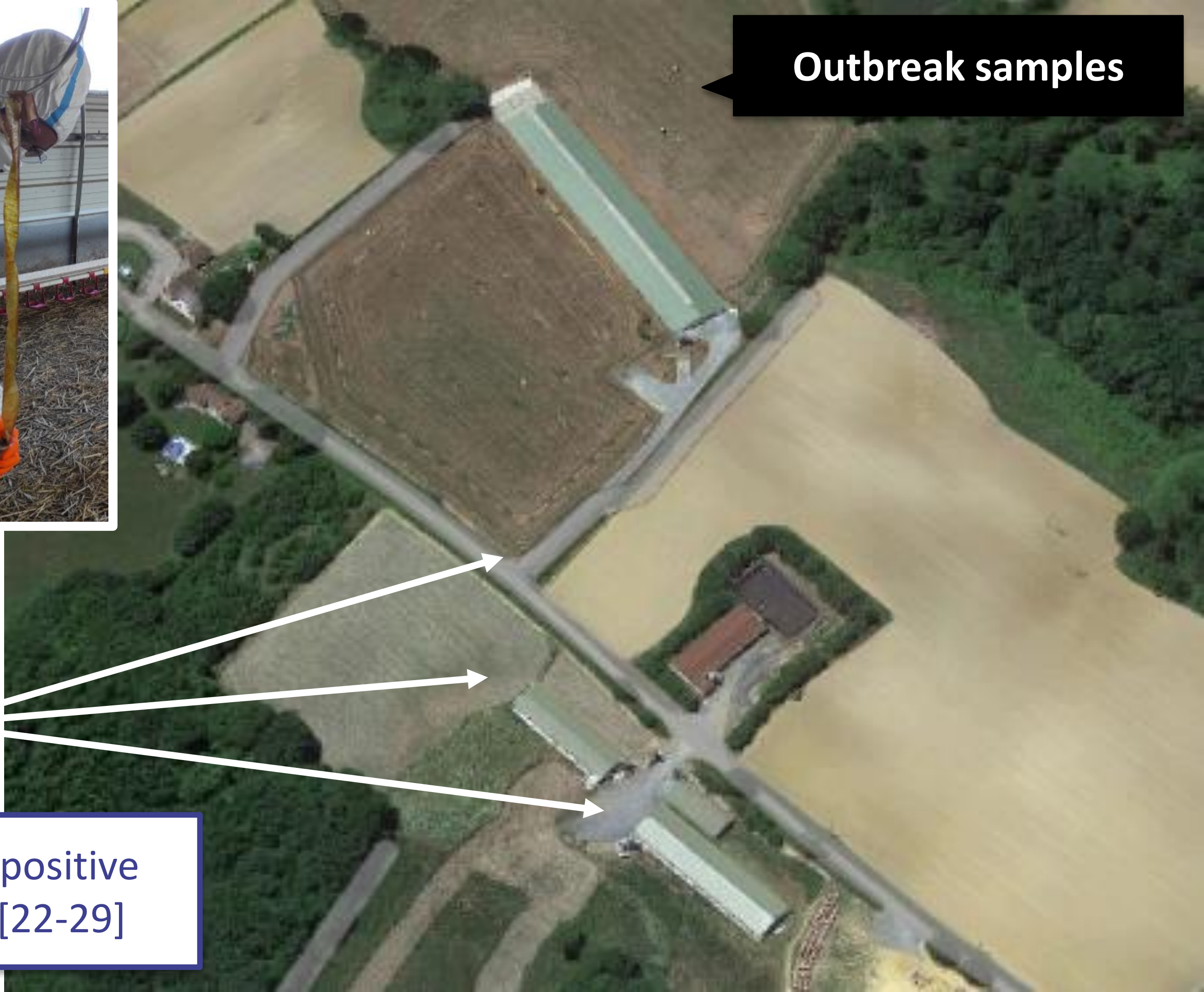
Sawabe et al, 2006

- H5N1, Japan, 2004
- 926 flies collected

vRNA detection and virus isolation up to 2.3 km



Flies

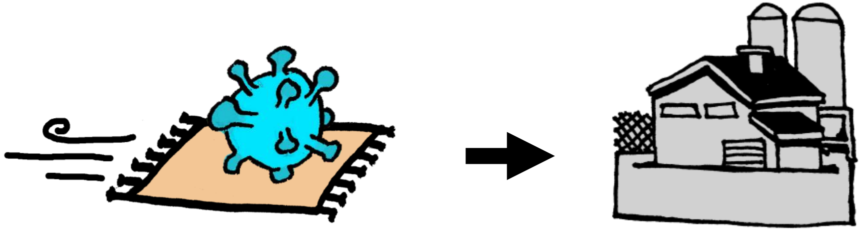


Outbreak samples

HPAI-positive
Ct ~ [22-29]

Transport of aerosols : **wrap-up!**

- Parameters to take into account
  - **Particle** characteristics
    - Diameter
    - Humidity
    - Type of organic matter
  - Special particles: live **insects**, **feathers**!
  - **Temperature**, **humidity** and UV **radiation**
  - **Wind** velocity
  - **Distance** between farms



Arrival of bioaerosols
and pathogens in farms.
“What do we know?”

Arrival of bioaerosols and pathogens in farms

Article

Monitoring Wind-Borne Particle Matter Entering Poultry Farms via the Air-Inlet: Highly Pathogenic Avian Influenza Virus and Other Pathogens Risk

Armin R. W. Elbers [1,*], José L. Gonzales [1], Miriam G. J. Koene [1], Evelien A. Germeraad [1], Renate W. Hakze-van der Honing [1], Marleen van der Most [1], Henk Rodenboog [2] and Francisca C. Velkers [3]

- Nets on air inlets

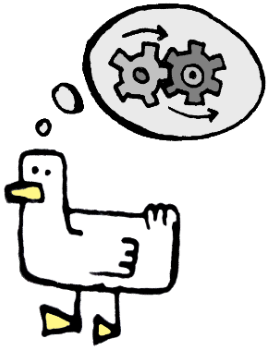
→ Collection of PM of variable **origin** and **size**
  - Mosquitoes, cobwebs
  - Seeds, leaf material
  - Plastic
  - Dry faeces

→ Larger PM in **stormy weather**

→ Some Campylobacter on PM, no HPAI

Arrival of bioaerosols and pathogens “in the poultry”

- Factors to take into account
  - Minimal infectious dose
    - Depends on the **virus/strain**
    - Depends on the **host**
    - **Duration** of exposition

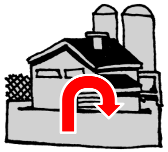


Biosecurity solutions.

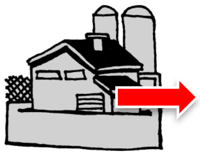
“What can we do?”

Overview of biosecurity solutions

Production of PM inside the barn

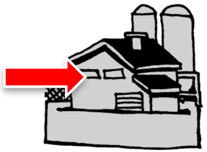


Emissions of PM out of the barn



PM / pathogens **emissions from outdoor**

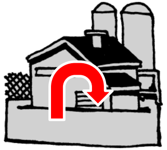
Entry of PM in the barns



Inactivation of airborne **pathogens**

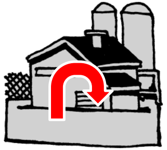
anything else?

Biosecurity: **production of PM** inside the barn



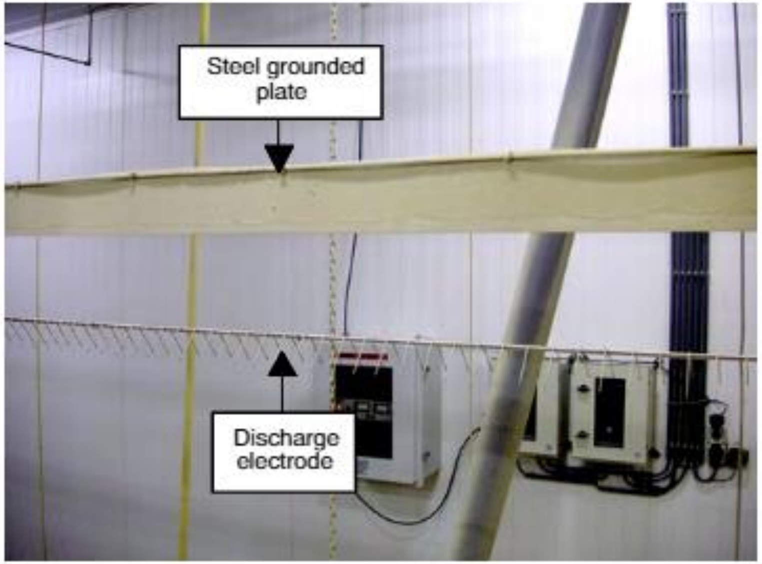
- Dust reduction
  - Oil (Canola, rapeseed) and water spraying? (Ogink et al, 2012)
  - Warning: foot pad lesions! Corrosion of metal, slippery floor…
- Modulation of animal activity?
- Modulation of human activity?

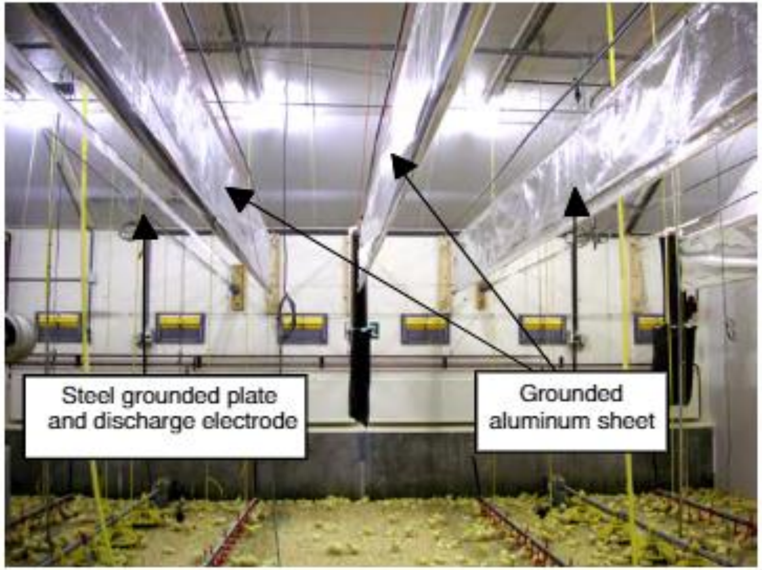
Biosecurity: **reduction of PM** inside the barn



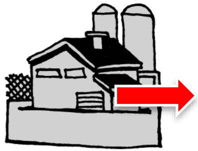
- **Filters** (see filter-types after) — Mostafa & Buescher, 2011
- **Ionization** systems inside the barns — Cambra-Lopez et al, 2009

Experimental set-up





Air outlet filtration systems



→ Associated with mechanical ventilation

- **Dry filters**

  Maintained efficacy in winter

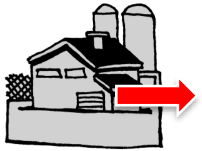
- **Air scrubbers**
  - Designed for ammonia and odor reduction
  - Spray of water +/- acid

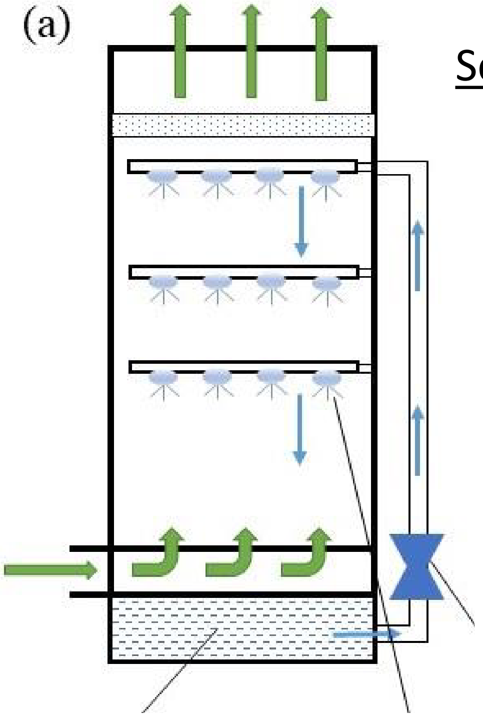
  Reduced efficacy in winter

- **Biofilters**
  - Filter bed with microorganism attachment
  - Used in combination with scrubbers

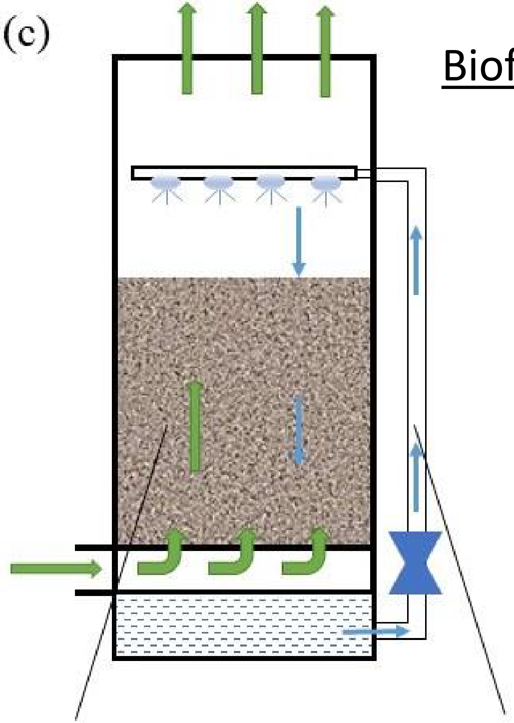
  Reduced efficacy in winter

<u>**Air outlet**</u> filtration systems





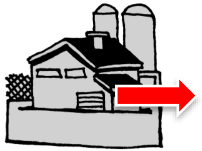
Scrubber



Biofilter

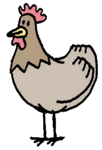
Guo et al, 2022

<u>Air outlet</u> filtration systems

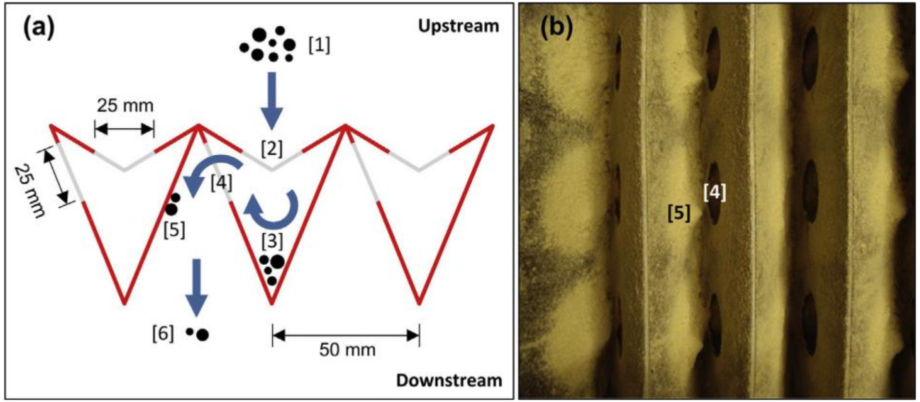


Winkel et al, 2015

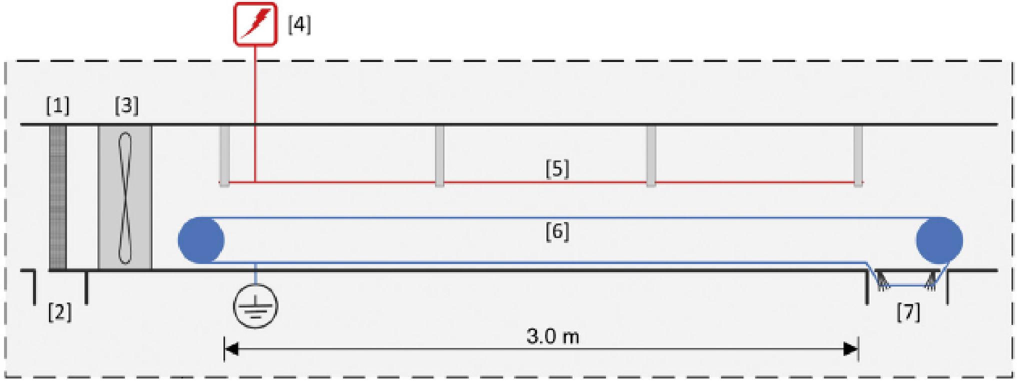
Farm trial



- **<u>Dry filter</u>**
  - ➢ PM_{10} 40.1% efficiency
  - ➢ $PM_{2.5}$ not significant



- **<u>Electrostatic precipitator</u>**
  - ➢ PM_{10} 57% reduction
  - ➢ $PM_{2.5}$ 45.3 % reduction

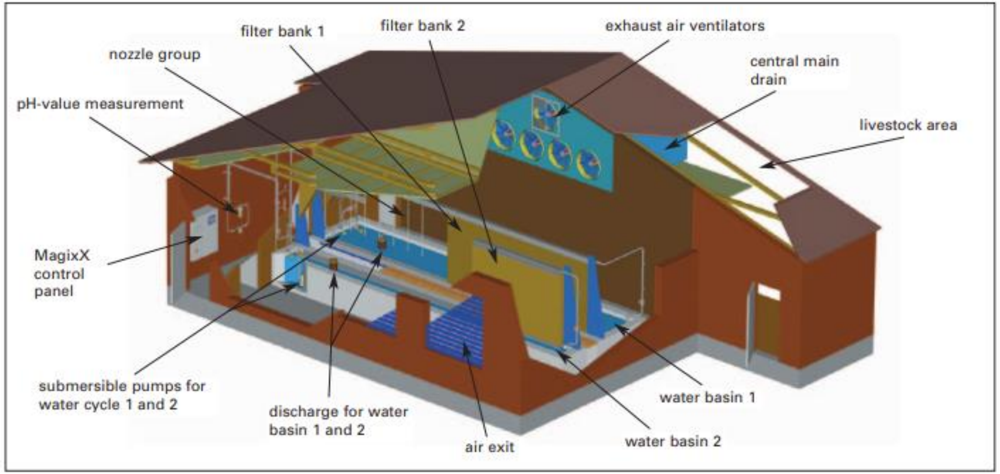


Air outlet filtration systems

On the field

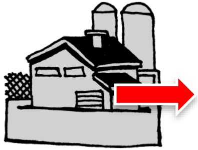
With water sprays

Basic construction of the MagixX exhaust air washer



Source: BigDutchman

Air outlet filtration systems



On the field

Source: BigDutchman

Dry filter

Biosecurity: PM / pathogens **from outdoor** activities

- Spreading practices
  - Inactivation of pathogens prior to spreading
    - Composting, lime, oxygenation
    - Storage of manure in open-air?
  - Spreading technique!

Source: ENVT

http://www.lafranceagricole.fr/allier-economie-et-environnement-avec-un-batiment-ecolo--1,0,3385963877.html

https://protecteau.be/resources/shared/articles/epandage/mat-epandage-article.pdf

Air inlet filtration systems

- Swine, 80% of reduction of risk to be infected by PRRS (known aerosol transmission), using filters (estimated high-MERV, 14 to 16) (Alonso et al, 2013)

MERV grade = filter efficacy (may be adapted)

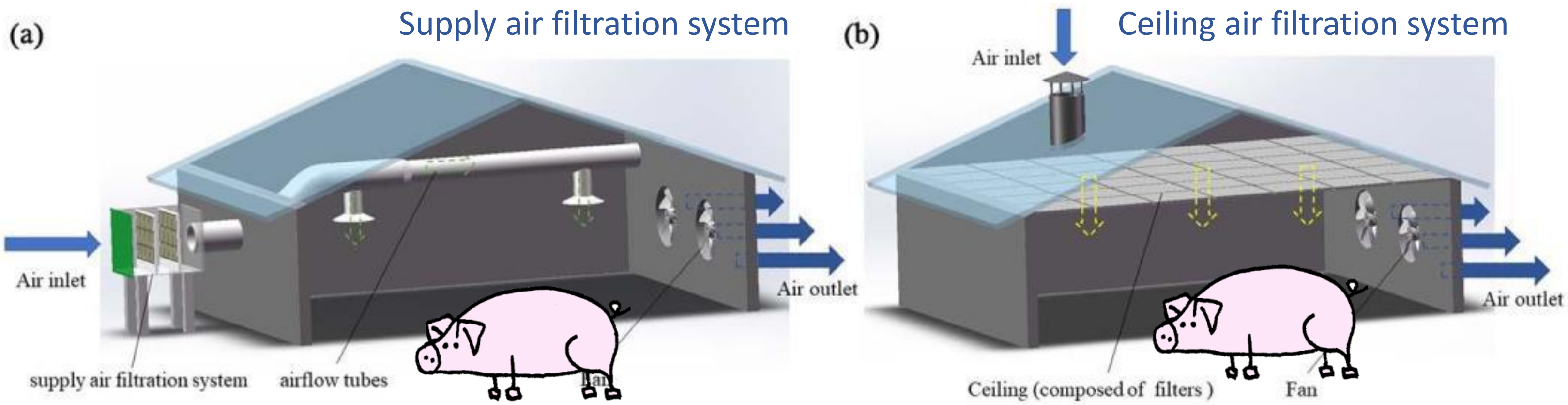
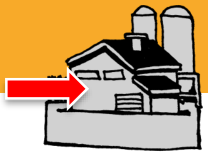
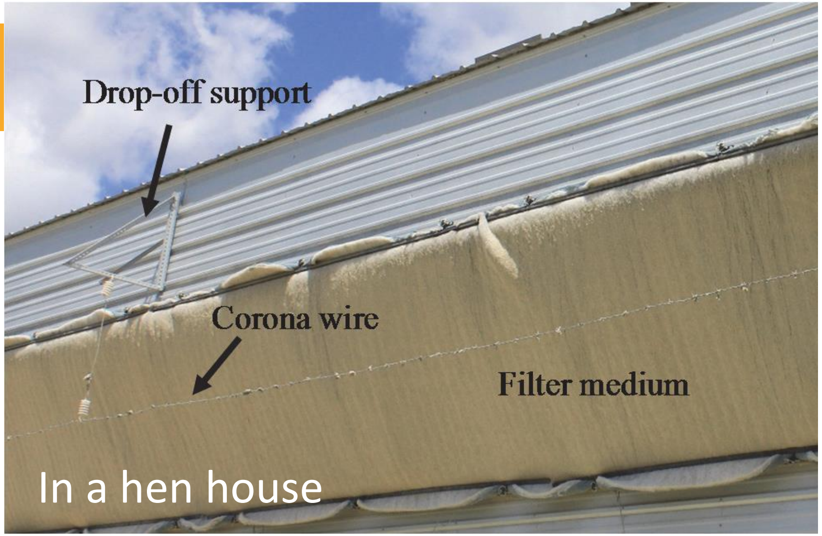


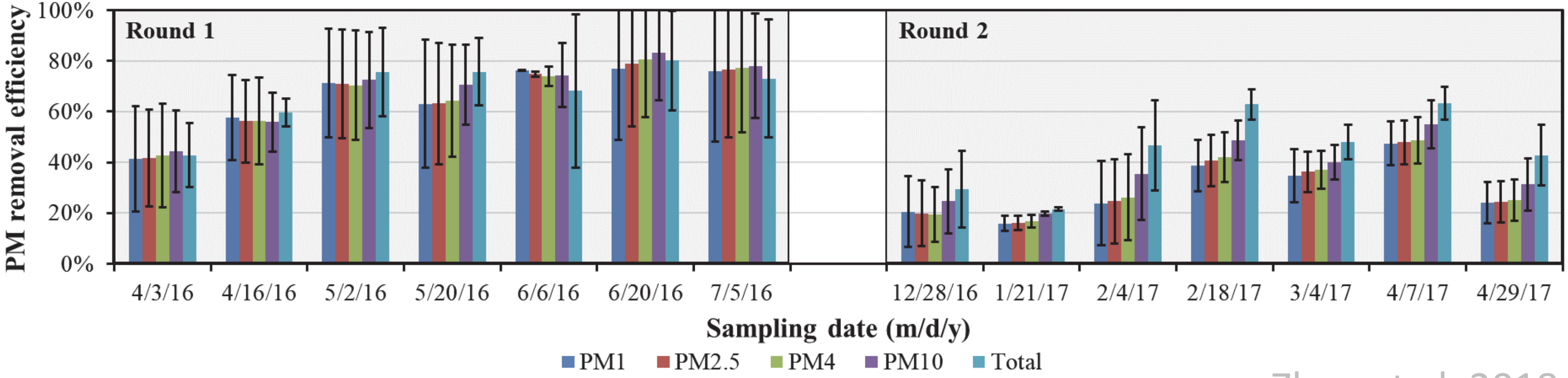
Illustration adapted from Guo et al, 2022

Air inlet filtration systems



- The electrostatic air filtration system
  - *low-grade air filter + electrostatic particle ionization*

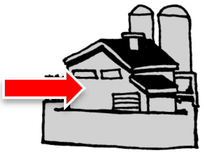




école nationale vétérinaire toulouse

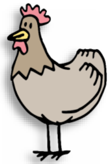
Zhao et al, 2018

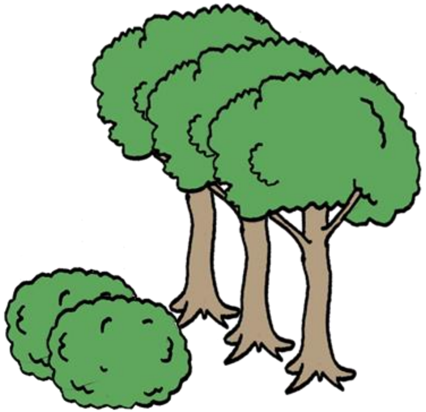
Vegetative Environment Buffers / Windbreaks



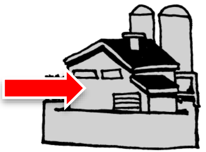
Green et al, 2023

Characteristic	Number of case farms (percent)	Number of control farms (percent)
Structural windbreak present (e.g., hill, natural break)	0 (0.0)	6 (30.0)

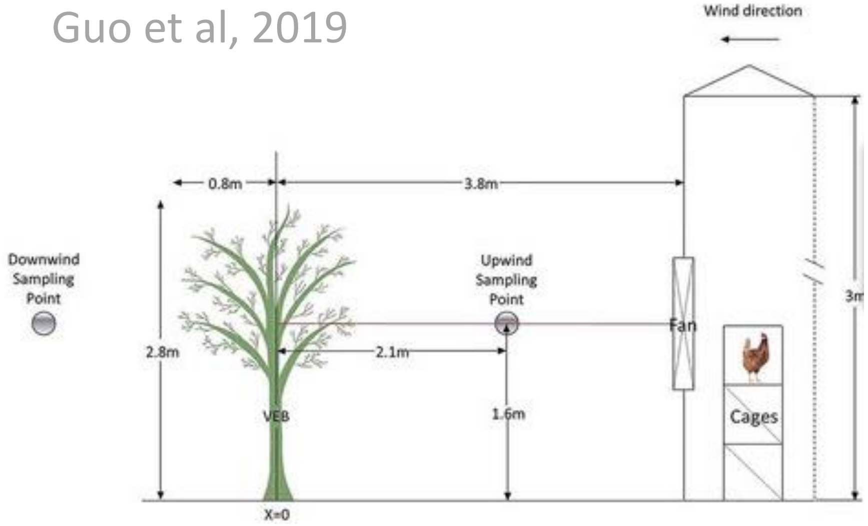


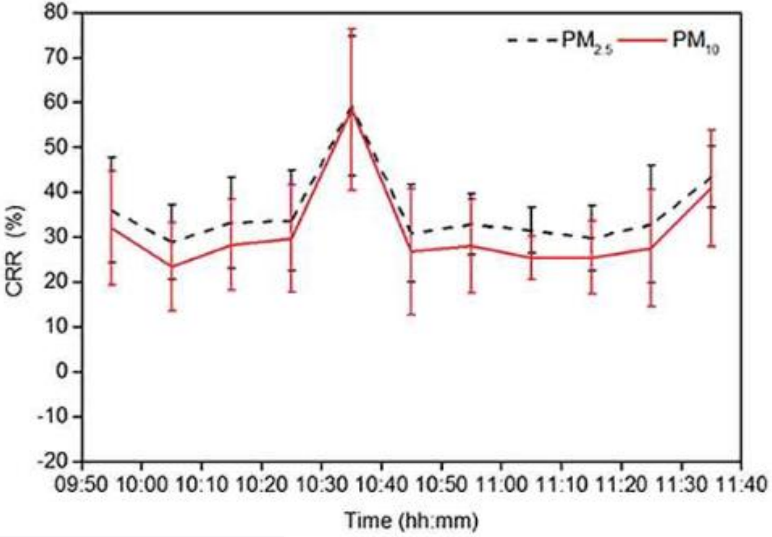


Vegetative Environment Buffers / Windbreaks



Guo et al, 2019

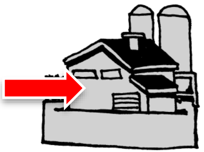




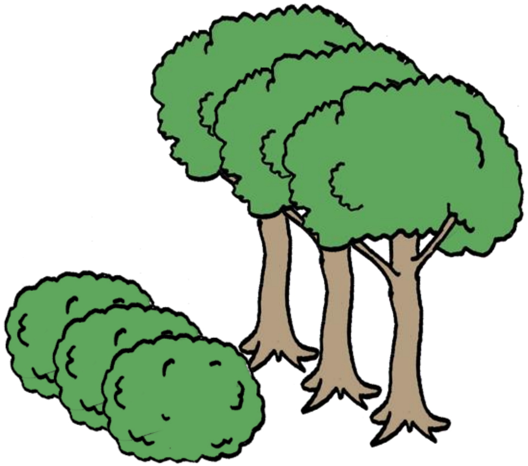
(b) WE

- Significant reduction of PM
- Efficacy depends on the type of tree

Vegetative Environment Buffers / windbreaks



- Mechanisms
  - Less speed = more settling
  - Adsorption on leaves
- Little technical info
  - Species, maintenance, design
- Multiple layers
- Not that expensive
  - Social, agroforestry, environmental benefits
  - Reduce winter heating costs, reduce summer cooling



Cleaning and disinfection of air inlets and outlets

Exhaust fans

Air inlets

Biosecurity

Pest control

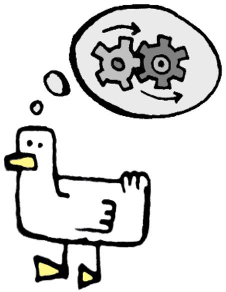
Biosecurity

Distance to road?
Protection from road?
Trees/hedges?

Legal requirements

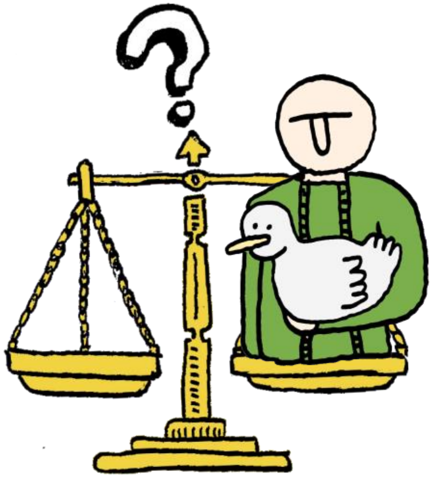
- Ministry of Health, **DECREE 30 May 2023,** Application methods of biosecurity measures in poultry farms. (23A03711) (GU General Series n.151 of 06-30-2023)
  - *Attachment 1. 3.a) xi.* ordinary poultry farms with a capacity greater than 250 animals located within high risk zones A and B adopt, where possible and **in particular if placed at a distance less than 1000 meters** from other farms of the same type, **systems aimed at reducing dispersion into the environment of dust coming out of warehouses** with extraction ventilation forced such as
    - **natural/artificial barriers** between two farms
    - or **nebulizers** in correspondence with the fans extraction;

Biosecurity solutions
“What should we do?”



So **is it worth** investing in airborne infections prevention?

- ✓ It is hard to be sure of the **extent of airborne transmission** for HPAI
  - ➢ Yet, it exists
  - ➢ “Even if it is negligible, we should not neglect it”
- ✓ Airborne infections are **perceived as important** by farmers
  - ➢ 20/28 farmers think that “airborne spread is the most likely route of infection”. Garber et al, 2016



So **is it worth** investing in airborne infections prevention?

- Air cleaning devices = **EXPENSIVE**
  - Useful for PM reduction, as well as pathogen
  - The level of efficacy (choice of technology, choice of filter) and the investment may be adapted
  - Reserved for high risk/ high value farms
- Classical cleaning and disinfection in and around the barn
  - Already part of biosecurity plans

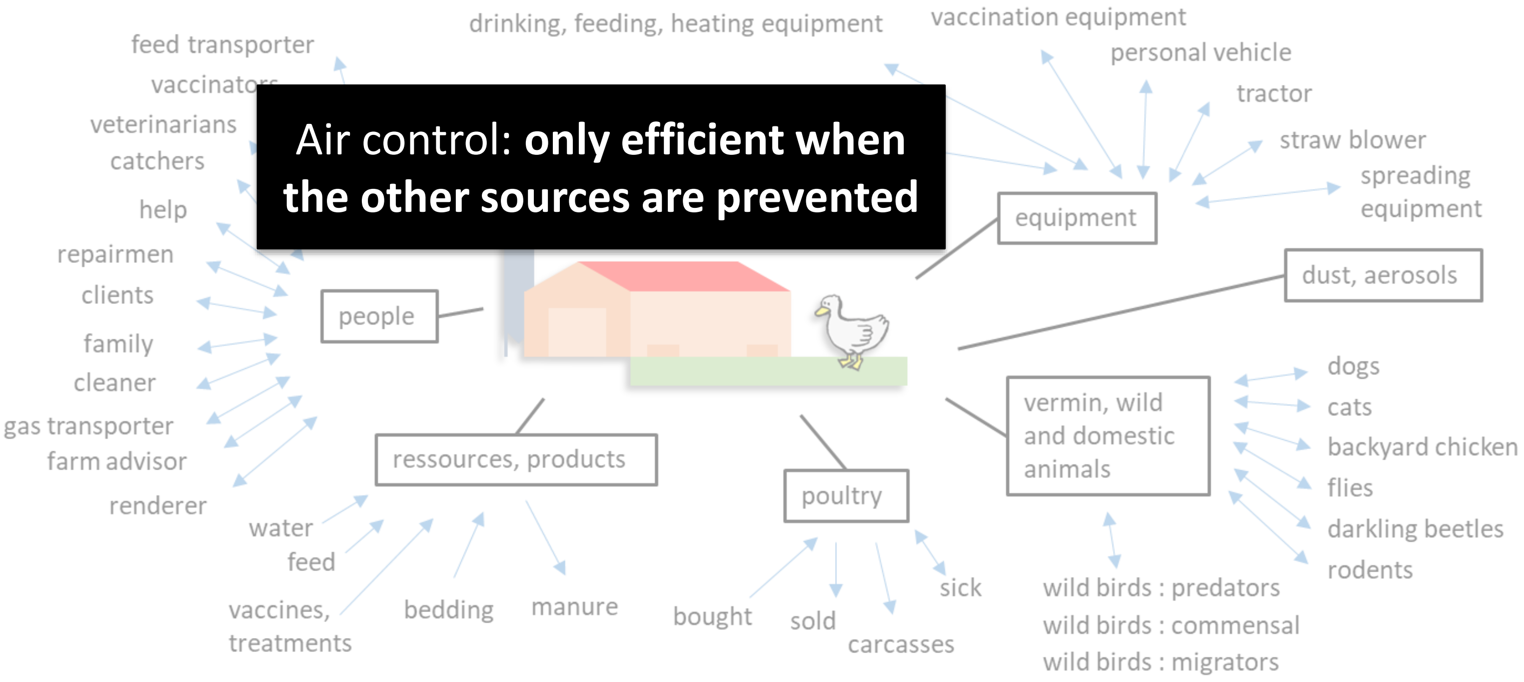
Cost-benefit analysis

So <u>**is it worth**</u> investing in airborne infections prevention?

- Other benefits when managing airborne transmission
  - ➢ Reduction of smell
  - ➢ Social acceptability
  - ➢ Wood production
  - ➢ Animal welfare
- Not doing something is already a choice
- Risk reduction, not necessarily 100%

So <u>is it worth</u> investing in airborne infections prevention?

Air control: **only efficient when the other sources are prevented**



Regional biosecurity measures

Farm density and airborne transmission…
… can we reduce farm density ?

- Ministry of Health, **DECREE 30 May 2023,** Application methods of biosecurity measures in poultry farms. (23A03711) (GU General Series n.151 of 06-30-2023)
    - *Attachment 1. 5.*
        - *Zones A and B. For opening new farms and conversions, Min. distance 1500 m from other poultry farms*
        - *1000 m, when out of zones A and B*

Regional biosecurity measures

Farm density and airborne transmission…
… can we reduce farm density ?

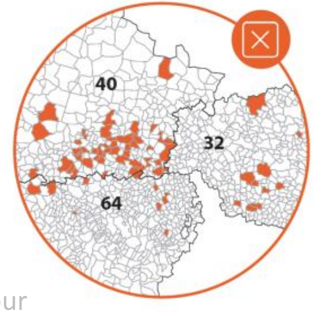
Vet Res. 2023 Jul 10;54(1):56. doi: 10.1186/s13567-023-01183-9.

Impact of palmiped farm density on the resilience of the poultry sector to highly pathogenic avian influenza H5N8 in France

Billy Bauzile [1], Benoit Durand [2], Sébastien Lambert [1], Séverine Rautureau [3], Lisa Fourtune [1], Claire Guinat [1], Alessio Andronico [4], Simon Cauchemez [4], Mathilde C Paul [1], Timothée Vergne [5]

Regional action!

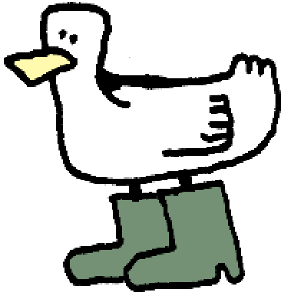
"Plan Adour", an industry-driven plan, to ban restocking in the most at-risk zones between 15.12.22 and 15.01.22



Source: Maïsdour

Thank you!

Any questions?



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