LIVESTOCK ODOR STUDY COMMITTEE

NOVEMBER 28, 2007

PRESENTATION BY

DR. PATRICK G. HALBUR AND
DR. JEFF ZIMMERMAN

COLLEGE OF VETERINARY MEDICINE
IOWA STATE UNIVERSITY

A review of airborne transmission of pig diseases

College of Veterinary Medicine
Iowa State University

Iowa Legislature General Session
Livestock Odor Study Committee
November 28, 2007

Overview

- Airborne infectious diseases of pigs
- Research in airborne infectious diseases
- Current state of knowledge
  - Influenza and PRRS virus

Airborne infectious agents

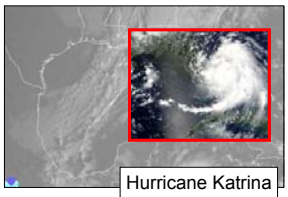
- Domestic agents
  - **Influenza viruses**
  - **PRRS virus ($600M/yr)**
  - *Mycoplasma hyopneumoniae*
  - *Actinobacillus pleuropneumoniae*
  - *Salmonella* spp.
  - TGE virus
- "Exotic" agents
  - Foot-and-mouth disease virus
  - Hog cholera virus
  - African swine fever virus
  - Swine vesicular disease virus
  - Pseudorabies virus

Aerosol research objectives:

1. Develop a body of knowledge
2. Predict events
3. Develop interventions

Aerosol research objectives:

1. Develop a body of knowledge
2. Predict events
3. Develop interventions



Hurricane Katrina
August 25, 2005

An aerosol example ...

1. Develop a body of knowledge
2. Predict events
3. Develop interventions

Knowledge ➡ Prediction ➡ *Intervention*

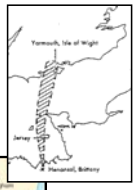
- March 1981, outbreaks of FMDV on 13 swine farms in Brittany and 1 in Normandy.

Knowledge ➡ Prediction ➡ *Intervention*

- March 1981, outbreaks of FMDV on 13 swine farms in Brittany and 1 in Normandy.
- **Prediction**: transmission 186 miles to the coast of England.

Knowledge ➡ Prediction ➡ *Intervention*

- March 1981, outbreaks of FMDV on 13 swine farms in Brittany and 1 in Normandy
- **Prediction**: transmission 186 miles to the coast of England.
- **Intervention:**
  - Personnel in place
  - Detected infected cattle
  - Cattle removed
  - ***Catastrophe ($) avoided***



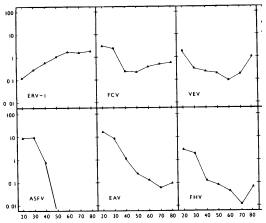
Knowledge ➡ Prediction ➡ *Intervention*

How'd they do it?

Knowledge ➡ Prediction ➡ *Intervention*

FMDV biology

1. How much FMDV shed by animals
2. Stability of airborne virus
3. Dose of virus required to infect animals

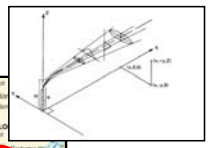


Effect of RH on stability of infectious virus

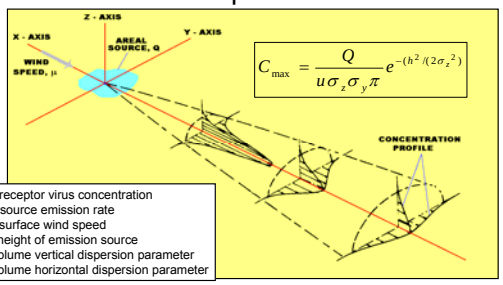
FMDV biology + meteorology

– Rate of virus decay under specific conditions.
- Temperature
- Relative humidity
- Cloud cover (UV)

– Virus dispersion
- Wind speed
- Wind direction



Gaussian plume model



$$C_{\max} = \frac{Q}{u\sigma_z\sigma_y\pi} e^{-(h^2/(2\sigma_z^2))}$$

C = receptor virus concentration
Q = source emission rate
U = surface wind speed
h = height of emission source
σ_z = plume vertical dispersion parameter
σ_y = plume horizontal dispersion parameter

Courtesy of Dr. Steven Hoff, Iowa State University

Current body of knowledge:

PRRS virus
Influenza virus

Brief history

- 1930's
  - Discovery of antibiotics makes *in vitro* culture possible
- 1945-1970
  - Bio-warfare research
  - Technology
  - Focus on potential weapons

Body of knowledge

- General absence of knowledge on airborne transmission
- *... minimal understanding of the dynamics of virus-laden aerosols ... ability to control and prevent virus spread is severely reduced, as was clearly demonstrated by SARS.*

Morawska L. 2006. Droplet fate in indoor environments, or can we prevent the spread of infection? Indoor Air 16:335-347.

Body of knowledge

- General absence of knowledge on airborne transmission
- Particularly true for livestock pathogens
- No <u>facts</u> on which to base site placement

Body of knowledge

- Stärk KDC. 1999. The role of infectious aerosols in disease transmission in pigs. Veterinary Journal 158:164-181.

Airborne infectious diseases in pigs: summary of accumulated evidence

Disease	*Field evidence*	*Isolation from air*	*% RH for best survival*	*Minimal infective dose*
Foot-and-mouth disease	yes	yes	>60	2.6 $\log_{10}$ LD_{50}
Swine vesicular disease	no	yes	>55	?
Aujeszky's disease (Pseudorabies)	yes	yes	55	4.5 $\log_{10}$ $TCID_{50}$
Influenza	yes	yes	?	?
Porcine respiratory and reproductive syndrome	yes	no	?	?
African swine fever	no	yes*	20–30	?
Classical swine fever	no	no	?	?
Porcine respiratory coronavirus	yes	yes	?	?
Enzootic pneumonia	yes	yes	<25 or >75†	?
Actinobacillosis	yes	yes	?	10^4–10^7 CFU/mL
Arthrophic rhinitis	yes	yes	75	?

? = not known. * Indirectly using mouse infection as a biological indicator. † Established with other *Mycoplasma* spp.

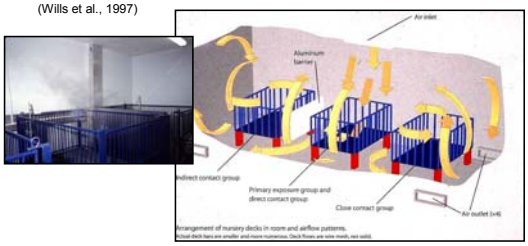
Body of knowledge

- Systematic reviews in progress
  - PRRS virus (J. Hermann)
  - Influenza viruses (Dr. Annette O'Connor, Dr. Christa Irwin)

PRRSV - evidence of aerosol transmission

- Experimental evidence

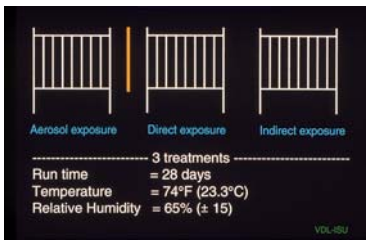
(Wills et al., 1997)



PRRSV - evidence of aerosol transmission

- Experimental evidence

aerosol 2/5
direct 5/5
indirect 3/5
(Wills et al., 1997)



PRRSV - evidence of aerosol transmission

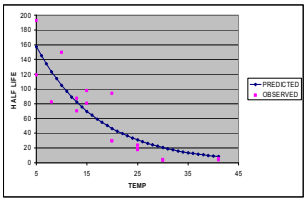
- Experimental evidence
  - Transmission from inoculated to susceptible pigs over a distance of one meter in 1 of 2 attempts. (Torremorell et al., 1997)
  - … 20 inches in 1 of 2 attempts. (Lager and Mengeling, 2000)
  - Transmission ... 2.5 m in infected animal air space, but not via exposure from exhaust fans over distances of 1 or 30 m. (Otake et al., 2002)
  - … one meter in 3 of 3 attempts. (Kristensen et al., 2002)

PRRSV - shedding by pigs

- Hermann et al. 2007. Detection of respiratory pathogens in air samples from acutely infected pigs. Can J Vet Res (in press)

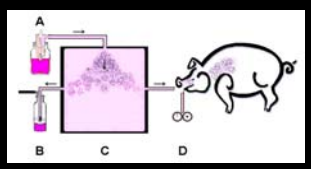
PRRS - stability in the air

- Hermann . 2006. Effect of temperature and relative humidity on the stability of infectious PRRSV in aerosols. Vet Res 38:81-93.



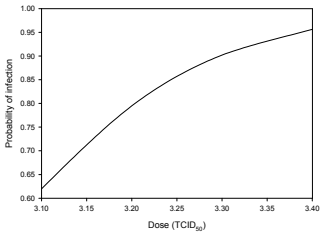
PRRSV - dose required to infect pigs

- Hermann. 2007. Dose-response estimates for PRRSV. Vet Microbiol (submitted)



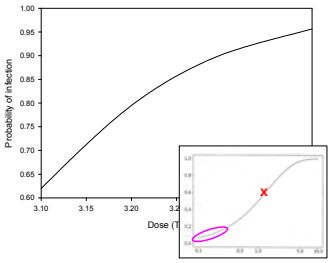
PRRSV infectious dose

PCR	TCID	Probability
4.0	3.14	0.60
4.2	3.19	0.69
4.4	3.23	0.76
4.6	3.29	0.83
4.8	3.34	0.87
5.0	3.39	0.91
5.2	3.49	0.94



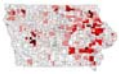
PRRSV infectious dose

PCR	TCID	Probability
4.0	3.14	0.60
4.2	3.19	0.69
4.4	3.23	0.76
4.6	3.29	0.83
4.8	3.34	0.87
5.0	3.39	0.91
5.2	3.49	0.94



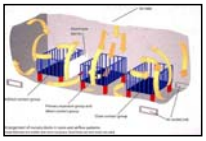
PRRSV - Summary

- SHED - at low levels
- STABLE - at low temperature
- DOSE required to infect the next pig?
  - In progress
- Not enough data to determine site placement



Influenza - evidence of aerosol transmission

- NO DATA equivalent in strength to PRRSV data
- Transmission studies with guinea pigs, mice, ferrets
  - Lowen et al. 2007. Influenza virus transmission is dependent on RH and temperature. PLoS Pathog 3(10):e151
  - Lower temperature
  - Lower relative humidity

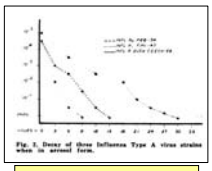


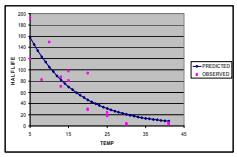
Influenza - shedding by pigs?

- NO DATA on respiratory aerosols from pigs
- Humans
  - Nasopharyngeal washes day 2 - 3 post infection
  - Up to 10^7 $TCID_{50}$ per ml
  - Big problems with indirect measures!!

Influenza - stability in the air

- Limited data
- Mitchell et al. 1966. Decay of influenza A viruses of human and avian origin. Can J Comp Med Sci 32:544-546.





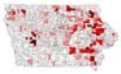
Temperature 70 F, RH 75%

Influenza - infectious dose for pigs?

- NO DATA on pigs
- Horses
  - 1 x 10^2 EID_{50} lowest infectious dose
    Mumford et al. 1990. Experimental infection of ponies with equine influenza (H3N8) viruses by intranasal inoculation or exposure to aerosols. Equine Vet J 22:93-98
- Humans
  - 1 x $10^{0.6}$ to 1 x 10^3 $TCID_{50}$
    Douglas RG. Influenza in man. 1975. In: The influenza viruses and influenza. New York: Academic Press. p. 375–447.
- <u>Problems</u> with extrapolation across species!!

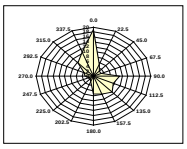
Influenza - Summary

- No data on respiratory SHEDDING by pigs
- Sparse data on STABILITY of airborne virus.
  - Assumptions: better stability at lower RH and temps
- No data on infectious DOSE
  - Highly infectious in equines and humans
- NOT enough data to determine site placement



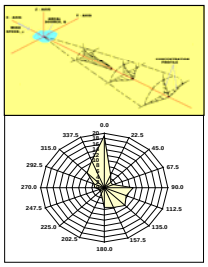
What do we need?

- Influenza
  - Shedding - Stability - Dose
    - IN PROGRESS: Koziel JA, Hoff SJ, Zimmerman JJ. Simultaneous treatment of odorants and pathogens emitted from CAFOs by advanced oxidation technologies. Binational Agricultural Research and Development Fund (BARD) - $48,000.
- PRRSV and influenza
  - "Baseline" field data



Baseline field data

- Objectives
  - Establish level and frequency of shedding
  - Estimate potential distance of spread
  - Evaluate effect of weather



Experimental design

1. Monitor PRRSV and influenza on 25 growing pig sites
2. Site samples
   - 12 samples per site
   - oral fluid sampling (n = 5)
   - air sampling (n = 1)
3. Test samples for viruses
   - PCR
   - Determine virus relatedness among sites in cluster

Omni 3000™ air sampler

Baseline field data

BUDGET*		
PRRSV PCV @ $25 per sample		$45,000
SIV PCR @ $40 per sample		$72,000
PRRSV sequencing (assume 6 per site) at $150		$22,500
SIV sequencing (assume 2 per site) at $150		$7,500
Two Omni™ 3000 @ $25,000		$50,000
Travel		$10,000
Wages, salary, tuition, fringe (2 years)		$70,000
TOTAL		$277,000

*Samples (25 sites x 12 samplings x 6 samples) = 1,800

Aerosol overview

1. Knowledge
   - Virus shedding by pigs
   - Stability of airborne infectious virus
   - Dose required to infect the next pig
2. Prediction
   - Where and when the virus will move
3. Intervention / Remediation
   - Filtration
   - Ultraviolet inactivation
   - Site placement

Thank you