Pathogen survival in swine environments
- putting it in context -

Jeff Zimmerman DVM PhD
Iowa State University
Topic

• A general review of the issues involved in the persistence of infectious pathogens in swine environments.
  – Other speakers will amplify on specific organisms or environments re concerns or interventions.
Brief retrospective

• Travel = disease transmission
  – Quarantine or prohibition of import

• Faster, farther transport = more outbreaks.
  – Legislation on movement of livestock
  – World Organisation for Animal Health (OIE) in 1924 after introduction of rinderpest into Europe and South American from Asia
In the U.S. ...

- Transport of Texas Cattle Fever to the north stimulated formation of USAHA
  - 1st meeting in Fort Worth, Texas (1897)
Transport biosecurity

- Indirect transmission
  - Infectious agent is transferred by a fomite (inanimate) or vector (living being)
  - Pigs + contaminated vehicles = infection
Conceptually simple ...

Pathogen shed into environment
Conceptually simple ...
Infectious dose reaches next load of pigs
Conceptually simple ...

- The devil is in the details
  - Dynamic = change x time
  - Multi-variate
The devil is in the details

1. **RATE** at which the environment is contaminated
2. **RATE** at which pathogen is inactivated in the environment
3. **RATE** at which transmission occurs in contaminated environment
RATE of contamination ...

- Magnitude & duration of shedding varies by **pathogen**
  - May differ by strain or isolate
  - Varies by **stage of infection**
  - Varies by **route of shedding** (urine, feces, etc)
  - Varies among individual **pigs**

- Level of contamination depends on how much **time** shedding animals spend in environment
Shedding varies by **stage of infection**

**Timeline for infection and disease.**
Rothman and Greenland. 1998 p 531

examples:
- SIV short period of shedding
- PRRSV long period of shedding
Shedding varies by **route**

<table>
<thead>
<tr>
<th>Source</th>
<th>Duration</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal Secretions</td>
<td>21 days</td>
<td>Benfield et al. 1994</td>
</tr>
<tr>
<td>Oral fluids</td>
<td>42 days</td>
<td>Wills et al. 1997</td>
</tr>
<tr>
<td>Urine</td>
<td>28 days</td>
<td>Rossow et al. 1994</td>
</tr>
<tr>
<td>Semen</td>
<td>92 days</td>
<td>Christopher-Hennings et al. 1995</td>
</tr>
<tr>
<td>Tonsil</td>
<td>175 days</td>
<td>Molina et al. 2007</td>
</tr>
<tr>
<td>Feces</td>
<td>&lt;35 days</td>
<td>Yoon et al. 1993</td>
</tr>
<tr>
<td>Milk and colostrum</td>
<td>Lactation</td>
<td>Wagstrom et al. 2001</td>
</tr>
</tbody>
</table>
• Magnitude & duration of shedding varies by pathogen
  – May differ by strain or isolate
  – Varies by stage of infection
  – Varies by route of shedding (urine, feces, etc)
  – Varies among individual pigs

• Level of contamination depends on how much time shedding animals spend in environment

• SO ... moving target. Plan for the worst.
RATE of inactivation ...

• Rate of inactivation dependent on ...
  – The pathogen’s innate stability
  – Environmental factors
    • Environmental matrix
      – Air
      – Liquid (water, urine, slurry)
      – Solid (ferrous, synthetic, organic)
    • Environmental conditions
      – Temperature, humidity, pH, sunlight
## Innate stability of pathogen

### Viruses of interest by family ...

<table>
<thead>
<tr>
<th>Family</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriviridae</td>
<td>PRRSV</td>
</tr>
<tr>
<td>Asfarviridae</td>
<td>African swine fever virus</td>
</tr>
<tr>
<td>Circoviridae</td>
<td>Porcine circoviruses</td>
</tr>
<tr>
<td>Coronaviridae</td>
<td>TGE, PRCV, hemagglutinating encephalomylitis virus, porcine epidemic diarrhea virus</td>
</tr>
<tr>
<td>Flaviviridae</td>
<td>Japanese encephalitis virus</td>
</tr>
<tr>
<td>Herpesviridae</td>
<td>Pseudorabies virus</td>
</tr>
<tr>
<td>Orthomyxoviridae</td>
<td>Influenza viruses</td>
</tr>
<tr>
<td>Paramyxoviridae</td>
<td>Rubulavirus, Nipah virus, Menangle virus</td>
</tr>
<tr>
<td>Parvoviridae</td>
<td>Porcine parvovirus</td>
</tr>
<tr>
<td>Pestiviridae</td>
<td>CSFV, BVDV</td>
</tr>
<tr>
<td>Picornaviridae</td>
<td>FMDV, swine vesicular disease, EMCV, porcine enteroviruses, porcine teschoviruses</td>
</tr>
<tr>
<td>Rhabdoviridae</td>
<td>Vesicular stomatitis virus</td>
</tr>
<tr>
<td>Reoviridae</td>
<td>Rotavirus</td>
</tr>
</tbody>
</table>
Environmental stability of CSFV

... CSFV is affected by ... physical and chemical variables ... temperature, humidity, pH, presence of organic matter, and exposure to various chemicals.


1903 - CSFV identified by de Schweinitz and Dorset
Environmental stability of CSFV

“It is impossible to give definitive guidelines for the survival time of CSFV in the environment.”

Methodological problem #1 …

• How to report environmental stability?

  – “Recovery over time” - not particularly useful
  – Half life (T1/2)
    • Time in which half of the pathogen is inactivated
    • For a specific pathogen and environmental conditions, T1/2 is always the same
    • Provides predictability
PRV half-life by RH & temp
Schoenbaum et al., 1990

<table>
<thead>
<tr>
<th>RH</th>
<th>4 C</th>
<th>22 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>85%</td>
<td>27.3*</td>
<td>17.4*</td>
</tr>
<tr>
<td>55%</td>
<td>43.6*</td>
<td>36.1*</td>
</tr>
<tr>
<td>25%</td>
<td>----</td>
<td>18.8*</td>
</tr>
</tbody>
</table>

*T1/2 in minutes
### PRV half-life by RH & temp

*Schoenbaum et al., 1990*

<table>
<thead>
<tr>
<th>RH</th>
<th>Temp</th>
<th><strong>T1/2</strong></th>
<th>Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 C</td>
<td>22 C</td>
<td>0</td>
<td>1/2^0</td>
</tr>
<tr>
<td>85%</td>
<td>27.3*</td>
<td>1</td>
<td>1/2^1</td>
</tr>
<tr>
<td>55%</td>
<td>43.6*</td>
<td>2</td>
<td>1/2^2</td>
</tr>
<tr>
<td>25%</td>
<td>----</td>
<td>3</td>
<td>1/2^3</td>
</tr>
<tr>
<td></td>
<td>18.8*</td>
<td>4</td>
<td>1/2^4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>1/2^5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>1/2^6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>1/2^7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>1/2^n</td>
</tr>
</tbody>
</table>

*T1/2 in minutes*
Methodological problem #2 …

• How to quantify infectious pathogens in the environment?
• Infectivity assays are mandatory
• PCRs?
  – PCRs **OVER REPORT** virus bx detect non-infectious
  – **UNDER REPORT** bacteria bx lack sensitivity
• Implications for monitoring or quantifying pathogens in the environment?
Infectious PRRSV in aerosols (half life by temperature)

Methodological problem #3 …

• No uniform SOPs to quantify environmental stability of infectious pathogens
  – Ex: uniform protocols for testing water
  – Ex: uniform protocols for disinfectants

• Develop uniform protocols for selected pathogens?
Methodological problems ...

1. How to report environmental stability?
   – Half-life (T1/2)

2. How to quantify infectious pathogens in the environment?
   – Infectivity assays

3. No uniform SOPs to quantify stability of infectious pathogens
   – Develop uniform protocols for selected pathogens
RATE of infection ...

• What is the **probability** that an exposure will result in infection? Depends on ...
  • Infectivity of pathogen
  • Susceptibility by route of exposure
  • Dose

• Number of exposures to the pathogen?
Probability of infection? Dose-response curve

- Describes the probability of infection x exposure dose
- $ID_{50} =$ dose predicted to cause infection in 50% of the exposed population
PROBABILITY of infection ...

• Depends on pathogen, route of exposure, and dose
  – HIV: unprotected sex has <10% probability of transmission.
    • Zero probability of spreading by coughing even though HIV is in saliva
  – Measles: A single exposure to a coughing person infected with measles results in infection in most susceptible persons
### PRRSV ID$_{50}$ X Route

<table>
<thead>
<tr>
<th>Route</th>
<th>ID$_{50}$</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parenteral (breaks in skin)</td>
<td>~10$^{1.0}$</td>
<td>1</td>
</tr>
<tr>
<td>Aerosols</td>
<td>&lt;10$^{3.1}$</td>
<td>125</td>
</tr>
<tr>
<td>Intranasal</td>
<td>10$^{3.9}$</td>
<td>~1000</td>
</tr>
<tr>
<td>Artificial insemination</td>
<td>10$^{4.5}$</td>
<td>~3000</td>
</tr>
<tr>
<td>Oral</td>
<td>10$^{5.2}$</td>
<td>~15,000</td>
</tr>
</tbody>
</table>
Summary and Conclusions

• Transport biosecurity - not a simple issue.
  – Foundation information is missing.

• Need to acquire or develop information on important pathogens:
  – Patterns of shedding
  – Environmental stability
  – Transmission characteristics
Summary and Conclusions

• In the absence of information, follow the tried and true:
  – Cleanliness - mandatory
  – Temperatures - the higher the better
  – Time - pathogens cannot live forever
  – Sunlight - desiccation + UV
  – Desiccation - one of the best methods