

# 14<sup>th</sup> Leman China Swine Conference

**Cost/Benefit Analysis of Air Filtration**

**空气过滤的成本/效益分析**

**Mark Schwartz**

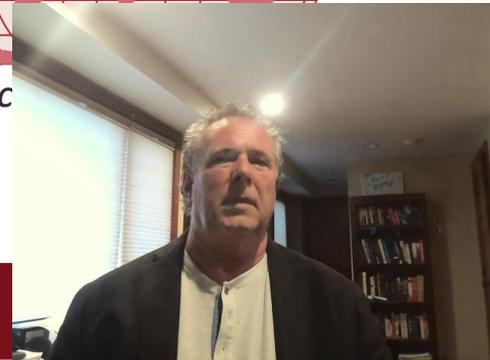
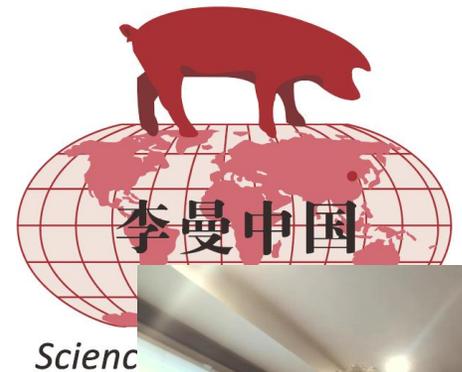
**University of Minnesota**

**October 18-20, 2025**

**Changsha International Conference**

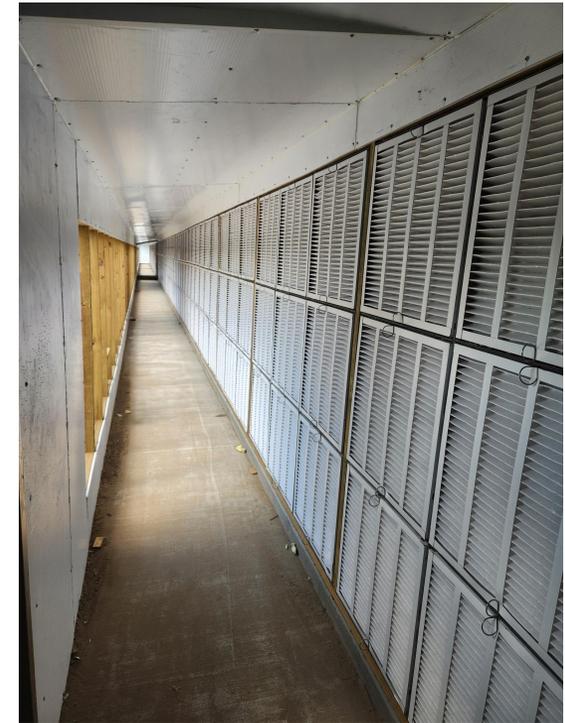
**Center**

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# Topics of Discussion 讨论主题

- **Filtering pig farms-brief history/timeline**  
过滤养猪场-简史/时间线
- **MSHMP database: outbreak incidence since 2009**  
MSHMP数据库：2009年以来的疫情发生率
- **Data: 数据：**
  - **Pre/post filtration outbreak frequency**  
过滤前/过滤后暴发频率
  - **Risk factors 危险因素**
- **Understanding filter rating 了解过滤器等级**
  - **MERV**
  - **Log reduction 对数减少**
- **Filtration cost/benefit analysis: examples and models**  
过滤成本/效益分析：实例与模型



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# US filtration history and timeline

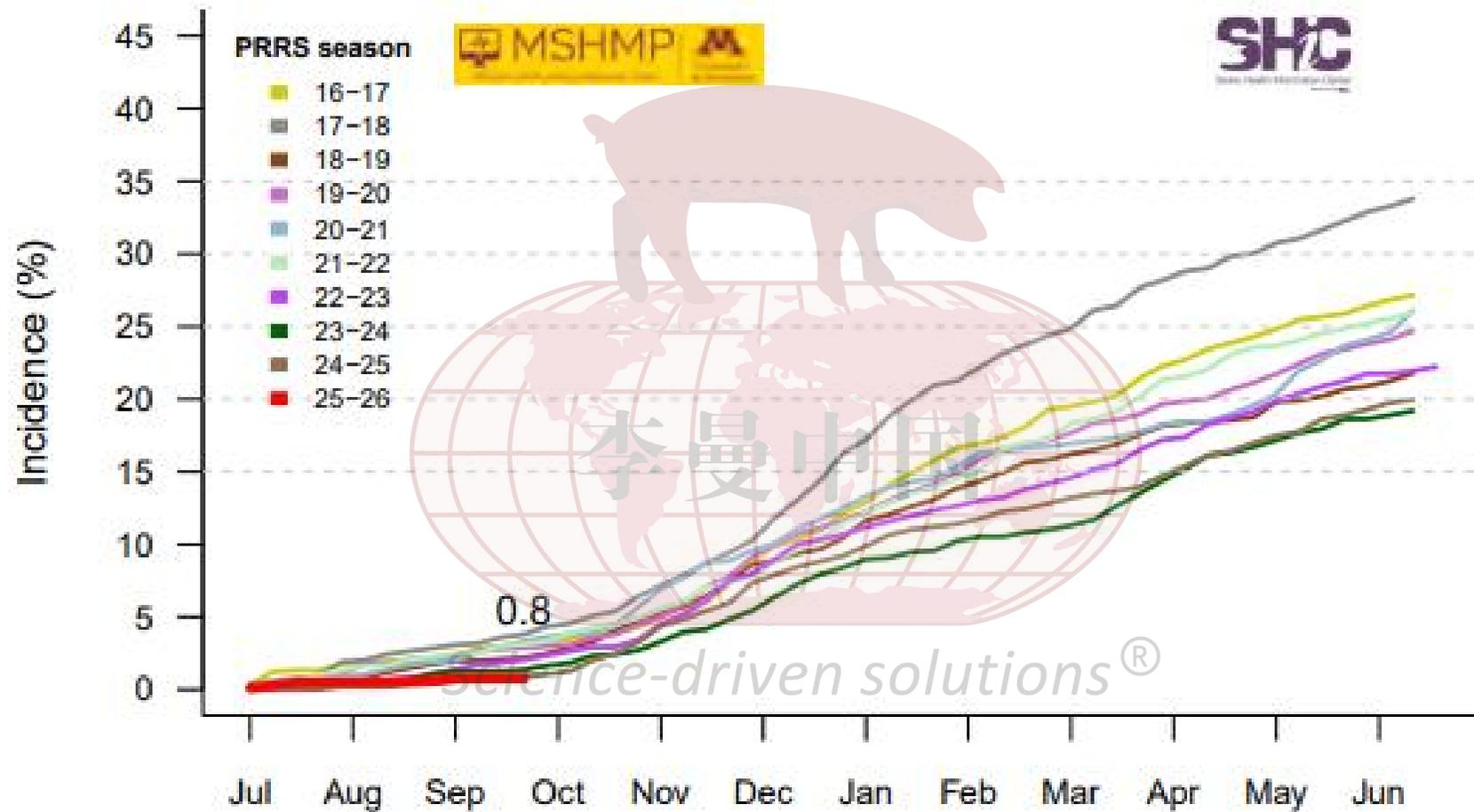
## 美国过滤历史和时间线

- **2002- HEPA filtration of a US boar stud**
- 2002年-美国种猪场HEPA过滤
- **2004- boar studs- MERV16**
- 2004年-种公猪-MERV16
- **2009- commercial sow farm filtration**
- 2009年- 商品母猪场过滤
- **2011-2015- rapid, widespread adoption of filtration of sow farms**
- 2011-2015年-母猪养殖场快速、广泛采用过滤技术
- **2025- estimated 15-20% of US commercial sow farms under filtration**
- 2025年, 预计美国15-20%的商业母猪农场将采用过滤技术



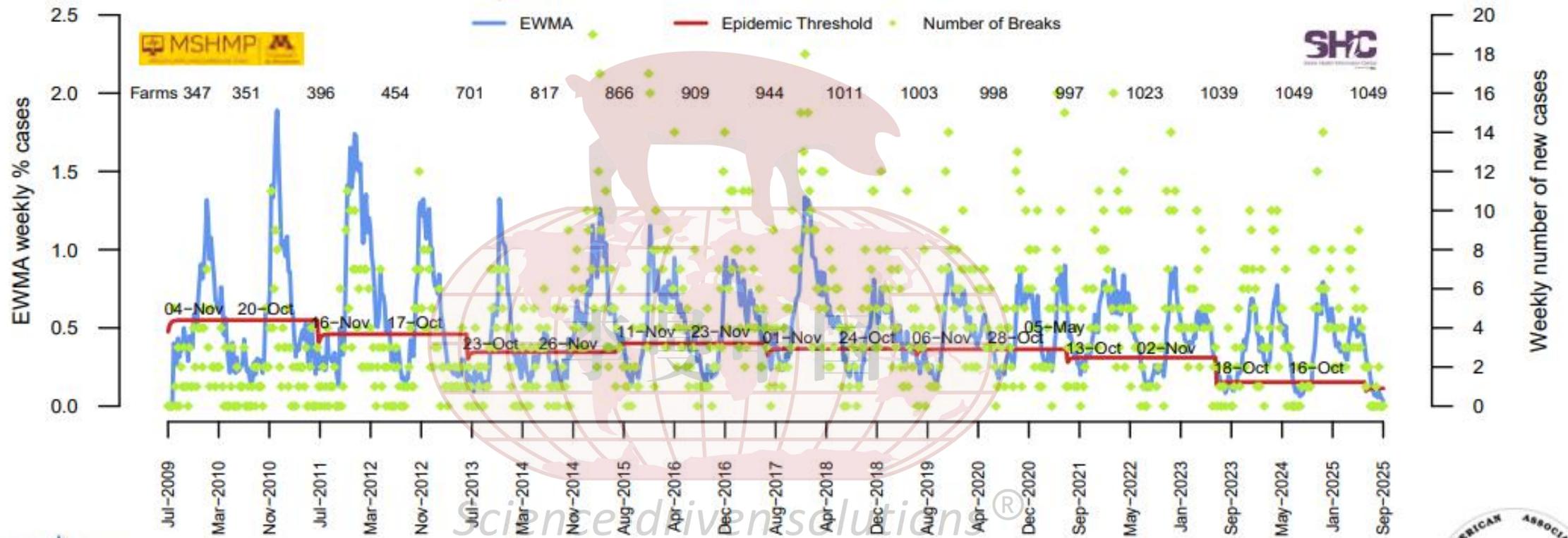
# Morrison Swine Health Monitoring Project

## 莫里森猪健康监测项目



# Morrison Swine Health Monitoring Project

## 莫里森猪健康监测项目



Publish date: September 26, 2025  
Visit the MSHMP website: <https://mshmp.umn.edu/> for extensive information.  
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# Risk factors for PRRSV introductions into pig populations

## PRRSV引入猪群的风险因素

- **Regional pig density**
  - Number of pig sites
  - Number of pigs per site
  - Health status of neighboring pig populations
- **Animal and semen movement**
- **Transport and traffic patterns**
- **Personnel and fomites**
- **Insects**
- **Wildlife**
- **Aerosol transmission**

区域生猪密度

养猪场数量

每个场地的猪数量

邻近猪群的健康状况

动物和精液运动

交通和运输模式

人员和污染物

昆虫

野生动物

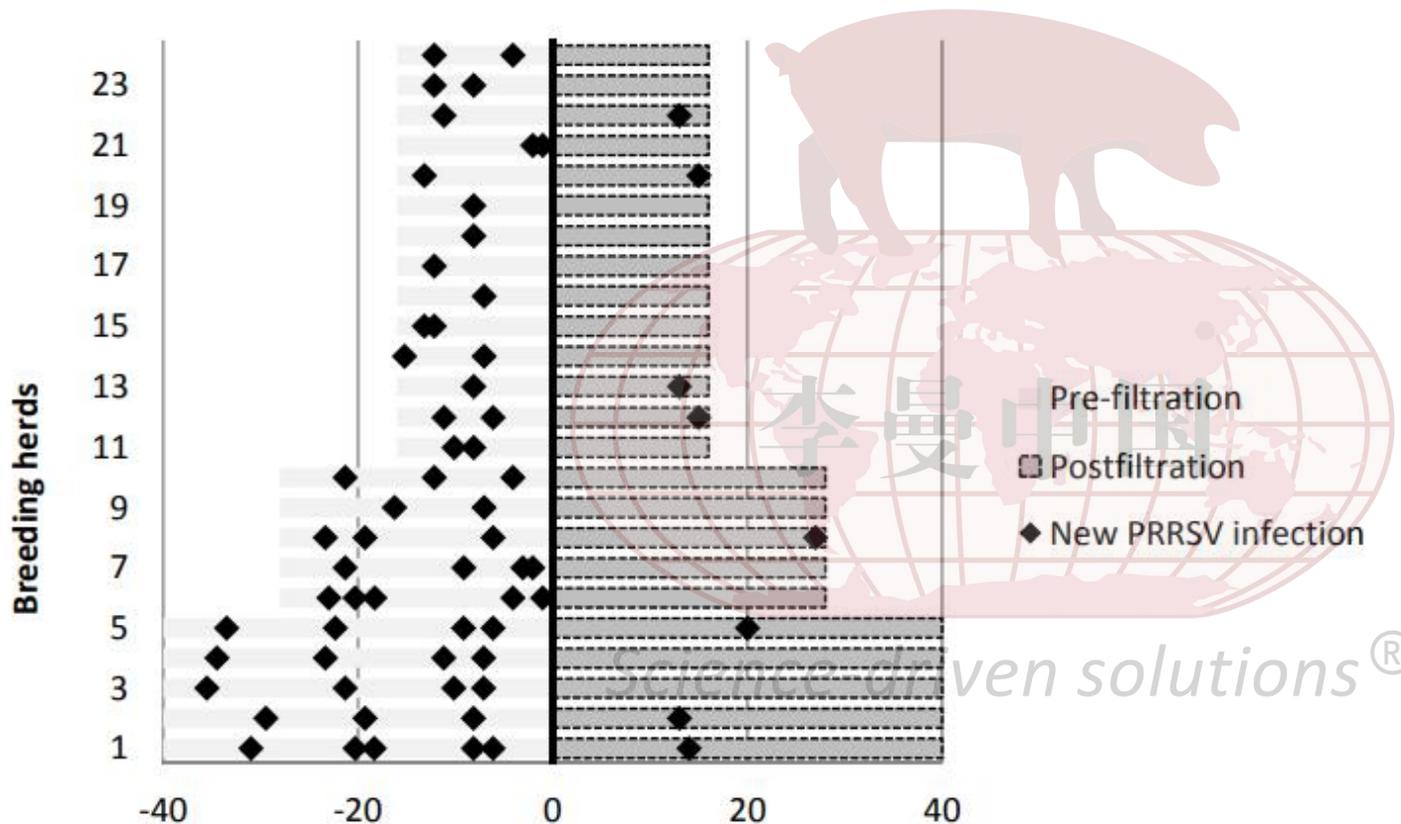
气溶胶传播

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# Detection of new PRRSV infections in breeding herds: pre and post filtration

## 在育种猪群中检测新的PRRSV感染：预过滤和后过滤



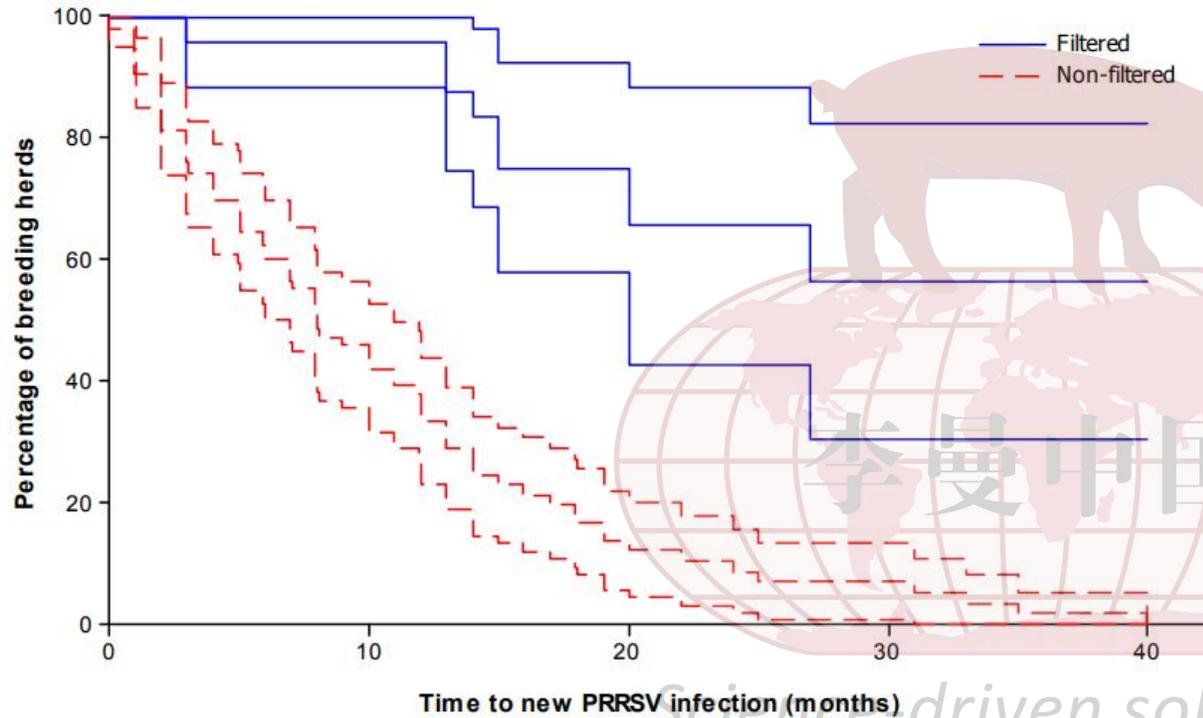
**Odds for a new PRRSV infection before air filtration 7.97 times higher than the odds after air filtration was initiated (CI: 3.77–16.85). \***  
在空气过滤之前，新PRRSV感染的几率比空气过滤开始后的几率高7.97倍（CI：3.77–16.85）。 \*

\*Dee S, Cano JP, Spronk G, Reicks D, Ruen P, Pitkin A, Polson D. Evaluation of the long-term effect of air filtration on the occurrence of new PRRSV infections in large breeding herds in swine-dense regions. *Viruses*. 2012 May;4(5):654-62.



# Evaluation of the long-term effect of air filtration on the occurrence of new PRRSV infections in large breeding herds in swine-dense regions\*

## 空气过滤对养猪密集地区大型养殖群中新PRRSV感染发生的长期影响的评估\*



**Kaplan-Meier curve: estimated survival functions, filtered and unfiltered farms.**

Kaplan-Meier曲线：估计的生存函数，过滤和未过滤的农场。

Group	Observations		Mean time to failure (months)	Standard Error	95% CI	
	Censored	Uncensored			Lower	Upper
Filtered	19	8	29.99	3.06	24	35.98
Non-filtered	19	79	10.74	1.03	8.72	12.75

\*Dee S, Cano JP, Spronk G, Reicks D, Ruen P, Pitkin A, Polson D. Evaluation of the long-term effect of air filtration on the occurrence of new PRRSV infections in large breeding herds in swine-dense regions. *Viruses*. 2012 May;4(5):654-62.



# Risk factors for PRRSV outbreaks in US breeding herds

## 美国种猪群中PRRSV暴发的风险因素

Summer Variable					Autumn Variable				
Variable	Levels	Coef (SE)	IRR (95 % CI)	p-value	Variable	Levels	Coef (SE)	IRR (95 % CI)	p-value
Intercept	-	-7.245 (0.320)			Intercept	-	-5.328 (0.208)		
Inventory	≥2500	0.448 (0.156)	1.56 (1.15–2.12)	0.004	Year	2013–2014	-0.457 (0.123)	0.63 (0.50–0.81)	<0.001
	<2500	Reference				2015–2018	-0.442 (0.105)	0.64 (0.52–0.79)	<0.001
Air-filter	Year-round	-0.396 (0.227)	0.67 (0.43–1.05)	0.082		2009–2012	Reference		
	Partial	0.161 (0.432)	1.17 (0.50–2.74)	0.710	Inventory	≥2500	0.308 (0.100)	1.36 (1.12–1.66)	0.002
Pigs/mile <sup>2</sup>	None	Reference				<2500	Reference		
	≥80 to <232	0.296 (0.311)	1.34 (0.73–2.47)	0.341	Air-filter	Year-round	-0.36 (0.146)	0.70 (0.52–0.93)	0.014
	≥232 to <460	1.23 (0.283)	3.42 (1.97–5.95)	<0.001		Partial	-0.098 (0.402)	0.91 (0.41–1.99)	0.807
	≥460	1.688 (0.281)	5.41 (3.12–9.38)	<0.001		None	Reference		
Region	<80	Reference			Pigs/mile <sup>2</sup>	≥80 & <232	0.018 (0.172)	1.02 (0.73–1.43)	0.916
	2	0.161 (0.370)	1.17 (0.57–2.43)	0.664		≥232 & <460	0.682 (0.159)	1.98 (1.45–2.70)	<0.001
	4	-0.685 (0.503)	0.50 (0.19–1.35)	0.174		≥460	1.042 (0.144)	2.83 (2.14–3.76)	<0.001
	5–6	-0.547 (0.359)	0.58 (0.29–1.17)	0.127	Region	<80	Reference		
	3	Reference			2	0.154 (0.271)	1.17 (0.69–1.98)	0.570	
					4	-1.778 (0.509)	0.17 (0.06–0.46)	<0.001	
					5–6	-0.898 (0.351)	0.41 (0.20–0.81)	0.010	
					3	Reference			

Sanhueza JM, Stevenson MA, Vilalta C, Kikuti M, Corzo CA. Spatial relative risk and factors associated with porcine reproductive and respiratory syndrome outbreaks in United States breeding herds. *Prev Vet Med.* 2020 Oct;183:105128.



# Risk factors for PRRSV outbreaks in US breeding herds

## 美国种猪群中PRRSV暴发的风险因素

Winter Variable				Spring Variable					
Variable	Levels	Coef (SE)	IRR (95 % CI)	p-value	Variable	Levels	Coef (SE)	IRR (95 % CI)	p-value
Intercept	-	-5.407 (0.196)			Intercept	-	-6.398 (0.225)		
Year	2013-2014	-0.606 (0.148)	0.55 (0.41-0.73)	<0.001	Year	2013-2014	-0.239 (0.195)	0.79 (0.54-1.15)	0.219
	2015-2018	-0.172 (0.114)	0.84 (0.67-1.05)	0.131		2015-2018	0.479 (0.151)	1.61 (1.20-2.17)	0.002
	2009-2012	Reference				2009-2012	Reference		
Inventory	≥2500	0.383 (0.099)	1.47 (1.21-1.78)	<0.001	Air-filter	Year-round	-0.460 (0.208)	0.63 (0.42-0.95)	0.027
	<2500	Reference				Partial	-0.282 (0.464)	0.75 (0.30-1.87)	0.544
Air-filter	Year-round	-0.681 (0.170)	0.51 (0.36-0.71)	<0.001		None	Reference		
	Partial	-0.577 (0.542)	0.56 (0.19-1.63)	0.287	Pigs/mile <sup>2</sup>	≥80 & <232	0.483 (0.195)	1.62 (1.11-2.38)	0.013
None	Reference			≥232 & <460		0.945 (0.178)	2.57 (1.82-3.65)	<0.001	
Pigs/mile <sup>2</sup>	≥80 & <232	0.237 (0.164)	1.27 (0.92-1.75)	0.149		≥460	1.005 (0.189)	2.73 (1.89-3.95)	<0.001
	≥232 & <460	0.585 (0.159)	1.79 (1.31-2.45)	<0.001	<80	Reference			
	≥460	1.041 (0.152)	2.83 (2.10-3.81)	<0.001	Region	2	0.464 (0.238)	1.59 (1.00-2.54)	0.052
<80	Reference			4		-0.985 (0.361)	0.37 (0.18-0.76)	0.006	
Region	2	-0.029 (0.266)	0.97 (0.58-1.64)	0.913		5-6	0.233 (0.233)	1.26 (0.80-1.99)	0.319
	4	-0.917 (0.356)	0.40 (0.20-0.80)	0.010	3	Reference			
5-6	0.053 (0.253)	1.05 (0.64-1.73)	0.834						
3	Reference								

Sanhueza JM, Stevenson MA, Vilalta C, Kikuti M, Corzo CA. Spatial relative risk and factors associated with porcine reproductive and respiratory syndrome outbreaks in United States breeding herds. *Prev Vet Med.* 2020 Oct;183:105128.



# Considerations in filtration system design and operation

## 过滤系统设计和操作中的注意事项

- **Full filtration** 全过滤
  - **Year-around** 全年无休
- **Partial filtration** 部分过滤
  - **Seasonal-unfiltered air in late spring-early autumn**
  - 晚春至早秋季节性未过滤空气
- **Negative pressure** 负压
- **Positive pressure** 正压
- **Filter rating** 过滤率
  - **MERV** *Science-driven solutions*®
- **Increased pressure drop and ventilation design and operation**
- 压降增大以及通风设计与操作



# Factors affecting the feasibility of air filtration

## 影响空气过滤可行性的因素

- Production model (multi-site vs single-site)
- 生产模式（多地点 vs 单地点）
  - Breed to wean 从繁殖到断奶
- New construction vs retrofit/remodel 新建与翻新/改造
- Ventilation system(s) 通风系统
- Historical outbreak rate 历史暴发率
- Regional pig density 区域生猪密度
- Filtration cost per sow 每头母猪的过滤成本
- Burden of disease 疾病负担
  - PRRSV outbreak cost per pig
  - 每头猪的PRRSV暴发成本



# MERV (Minimum Expected Reporting Value) and log reduction

## MERV (最小预期报告值) 以及日志减少

MERV (Minimum Efficiency Reporting Value)	Composite Average Particle Size Efficiency, % in size, $\mu\text{m}$		
	0.3-1.0	1.0-3.0	3.0-10.0
1	-	-	20% or better
2	-	-	20% or better
3	-	-	20% or better
4	-	-	20% or better
5	-	-	20% - 34%
6	-	-	35% - 49%
7	-	-	50% - 69%
8	-	20% or better	70% or better
9	-	35% or better	75% or better
10	-	50% - 64%	80% or better
11	20% or better	65% - 79%	85% or better
12	35% or better	80% or better	90% or better
13	50% or better	85% or better	90% or better
14	75% - 84%	90% or better	95% or better
15	85% - 94%	90% or better	95% or better
16	95% or better	95% or better	95% or better

**MERV14 E1 (0.30-1.0  $\mu\text{m}$ ) fractional efficiency – 75%**

MERV14 E1 (0.30-1.0微米) 分级效率 – 75%

**Penetration: 1 – fractional efficiency**

穿透力: 1 – 分数效率

**0.25**

**Log reduction =  $-\log(0.25) = \log(4)$**

对数减少量 =  $-\log(0.25) = \log(4)$

**0.60 log reduction 0.60对数减少**

**MERV16 E1 (0.30-1.0  $\mu\text{m}$ ) fractional efficiency – 95%**

MERV16 E1 (0.30-1.0微米) 分级效率 – 95%

**Penetration: 1 – fractional efficiency**

穿透力: 1 – 分数效率

**0.05**

**Log reduction =  $-\log(.05) = \log(20)$**

对数减少量 =  $-\log(0.05) = \log(20)$

**1.30 log reduction 1.30对数减少**

**Fractional efficiency:  $1 - 10^{-LR}$**

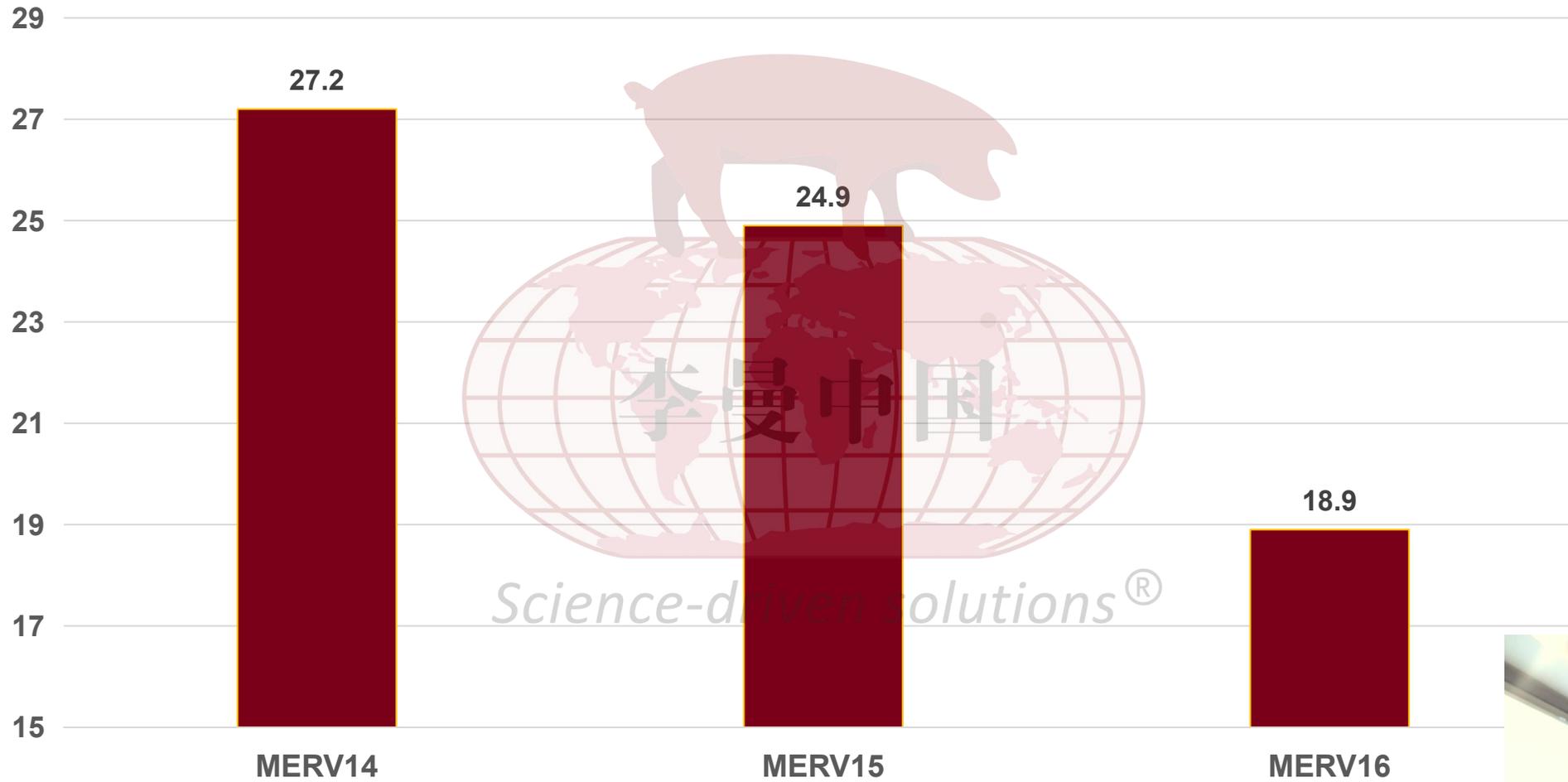
分数效率:  $1 - 10^{-LR}$

**$1 - 10^{-3} = 0.999$**

Credit: Air Quality Engineering, Inc.



# Cubic meters/minute airflow, 0.20 static pressure (in. w.c.) 立方米/分钟的气流，0.20的静压（英寸水柱）



# Model assumptions in developing a cost/benefit analysis

## 进行成本/效益分析时的模型假设

- **Historical outbreak rate 历史暴发率**
    - **New introductions or re-break of resident variants?**  
– 新引入或重新暴发的常存变种?
  - **Post-filtration outbreak rate estimate**
  - 过滤后暴发率估计
  - **Burden of disease 疾病负担**
    - **Cost per pig of each PRRSV outbreak**  
– 每次PRRSV暴发每头猪的成本
  - **Air filtration is more feasible with:**
    - **Increased outbreak cost per pig**
    - **History of frequent PRRSV outbreaks**
    - **Cost of filtration is lower**
- 空气过滤更可行的是：  
每头猪的暴发成本增加  
频繁暴发PRRSV的历史  
过滤成本较低



# Model assumptions in developing a cost/benefit analysis

## 成本/效益分析中的模型假设

- Hypothetical example of filtered vs unfiltered outbreak rate and costs
- 过滤与未过滤暴发率和成本的假设示例

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Unfiltered		\$1,015,000		\$1,015,000		\$1,015,000		\$1,015,000		\$1,015,000		\$1,015,000		\$1,015,000	
Filtered	\$3,750,000														
Filtered	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000	\$65,000
Filtered	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000	\$25,000
Filtered outbreak						\$1,015,000									

- **A negative NPV: net cost/pig is reduced with filtration**
- 负净现值：通过过滤，每头猪的净成本得以降低
- **Net present value (NPV) 净现值 (NPV)**
  - **Cost of filtration 过滤成本**
  - **Cost of outbreaks 疫情暴发的代价**
  - **5% discount rate used for NPV calculations**
  - 净现值计算中使用的5%的折现率



**Assumptions: Unfiltered outbreak rate: every 24 months**

**假设：未过滤暴发率：每24个月**

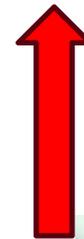
**Filtered outbreak rate: every 60 months**

**过滤暴发率：每60个月**

	PRRSV cost/weaned pig								
	\$4.00	\$5.00	\$6.00	\$7.00	\$8.00	\$9.00	\$10.00	\$11.00	\$12.00
\$350	0.2026	0.006	<b>-0.1907</b>	-0.3874	-0.5841	-0.7808	-0.9774	-1.1741	-1.3708
\$450	0.4853	0.2886	0.0919	<b>-0.1047</b>	-0.3014	-0.4981	-0.6948	-0.8914	-1.0881
\$550	0.768	0.5713	0.3746	0.1779	<b>-0.0187</b>	-0.2154	-0.4121	-0.6088	-0.8055
\$650	1.0506	0.854	0.6573	0.4606	0.2639	0.0672	<b>-0.1294</b>	-0.3261	-0.5228
\$750	1.3333	1.1366	0.9399	0.7433	0.5466	0.3499	0.1532	<b>-0.0434</b>	-0.2401

Filtration  
cost/sow  
过滤成本  
/母猪

Net present value of filtration implementation,  
operation and replacement, 15 year time period  
15年期间过滤实施、运行和更换的净现值



**Assumptions: Unfiltered outbreak rate: every 18 months**

**假设：未过滤的暴发率：每18个月**

**Filtered outbreak rate: at 72 months**

**过滤暴发率：72个月**

PRRSV cost/weaned pig

	\$2.00	\$3.00	\$4.00	\$5.00	\$6.00	\$7.00	\$8.00	\$9.00	\$10.00	\$11.00	\$12.00
\$350	0.2517	<b>-0.1171</b>	-0.4859	-0.8547	-1.2235	-1.5923	-1.9611	-2.3299	-2.6987	-3.0675	-3.4363
\$450	0.5344	0.1656	<b>-0.2032</b>	-0.572	-0.9408	-1.3096	-1.6784	-2.0472	-5.2008	-2.7848	-3.1536
\$550	0.8171	0.4483	<b>0.0795</b>	-0.2893	-0.6581	-1.0269	-1.3957	-1.7645	-2.1333	-2.5021	-2.8709
\$650	1.0997	0.7309	0.3621	<b>-0.0067</b>	-0.3755	-0.7443	-1.1131	-1.4819	-1.8507	-2.2195	-2.5883
\$750	1.3824	1.0136	0.6448	0.276	<b>-0.0928</b>	-0.4616	-0.8304	-1.1992	-1.568	-1.9368	-2.3056

Filtration cost/sow  
过滤成本/母猪



Net present value of filtration implementation,  
operation and replacement, 15 year time period  
15年期间过滤实施、运行和更换的净现值

Science-driven solutions



# Ventilation design and management considerations

## 通风设计和管理考虑因素

### Increased pressure drop with filtration

### 过滤时压降增加

<u>Static Pressure</u> <u>in. water</u>	<u>Speed</u> <u>rpm</u>	<u>Airflow</u> <u>cfm</u>	<u>Efficiency</u> <u>cfm/Watt</u>
0.00	-	-	-
0.065	575	29,600	20.3
0.10	574	28,200	18.8
0.15	573	26,400	17.2
0.20	572	23,900	15.2
0.25	571	20,900	13.1
0.30	571	17,400	10.9

Bioenvironmental and Structural Systems Laboratory 生物环境与结构系统实验室  
University of Illinois, Department of Agricultural and Biological Engineering 伊利诺伊大学农业与生物工程系



# Key points and summary 关键点与总结

- Data indicates that air filtration *reduces* the frequency of PRRSV outbreaks
- 数据表明，空气过滤可 *降低* PRRSV 爆发的频率
  - Pre/post filtration dataset 预/后过滤数据集
  - Incidence rate ratio of filtered vs. unfiltered sow farms
  - 过滤母猪场与未过滤母猪场的发病率比
- Mechanical filters *reduce* the quantity of particles
- 机械过滤器 *减少* 颗粒数量
  - Does not eliminate virus-laden particles 无法消除携带病毒的颗粒
  - Larger particles are captured at a higher rate than smaller particles
  - 较大颗粒的捕获率高于较小颗粒
  - MERV rating: MERV等级:
    - Air flow vs particle capture tradeoff 气流与颗粒捕获的权衡



# Key points and summary 关键点与总结

- **The feasibility of air filtration is a function of:** 空气过滤的可行性取决于以下因素:
  - **The historical outbreak rate of a sow farm** 母猪场的历史暴发率
  - **The ability to control non-aerosol modes of entry** 控制非气溶胶进入方式的能力
  - **The cost of filtration** 过滤的成本
  - **The burden of disease (cost per outbreak)** 疾病负担（每次暴发的成本）
- **Filtered sow farms operate in pig-dense regions**
- **过滤母猪场在养猪密集地区运营**
  - **(There is little/no advantage to filter sow farms in low-dense regions)**
  - **(在低密度地区，对母猪场进行过滤几乎没有/没有优势)**
    - **Filtering sow farms in low-dense regions will increase the cost of production**
    - **在低密度地区筛选母猪场会增加生产成本**
- **Filtration is one component of the biosecurity program**
- **过滤是生物安全计划的一个组成部分**
  - **All components of biosecurity must be sound**
  - **生物安全的所有组成部分都必须健全**



# Thank you!

# 非常感谢!

