

## Supplementary Material

### 1. Additional information on UV light measurements

Supplementary Tables 1 – 2 show that light intensity at other wavelengths was also detected besides the wavelength of the lamp.

**Supplementary Table S1.** Summary of UV light intensities for UV-C germicidal (254 nm) measured using a UV radiometer with four different wavelength detector/filter combinations (185 nm, 220 nm, 254 nm, and 365 nm, respectively).

UV-C germicidal (254 nm) lamp	Light intensity (mW/cm <sup>2</sup> ) at 185 nm	Light intensity (mW/cm <sup>2</sup> ) at 220 nm	Light intensity (mW/cm <sup>2</sup> ) at 254 nm	Light intensity (mW/cm <sup>2</sup> ) at 365 nm
Treatment 1	-*	-	<b>3.43</b>	0.02
Treatment 2	-	-	<b>4.40</b>	0.03
Treatment 3	-	-	<b>5.04</b>	0.03
Treatment 4	-	-	<b>5.35</b>	0.03
Treatment 5	-	-	<b>5.35</b>	0.03
Treatment 6	-	-	<b>5.06</b>	0.03
Treatment 7	-	-	<b>4.53</b>	0.02
Treatment 8	-	-	<b>3.57</b>	0.02

\*The light intensity is too low to be recorded.

**Supplementary Table S2.** Summary of UV light intensities for UV-C excimer (222 nm, unfiltered) measured using a UV radiometer with four different wavelength detector/filter combinations (185 nm, 220 nm, 254 nm, and 365 nm, respectively).

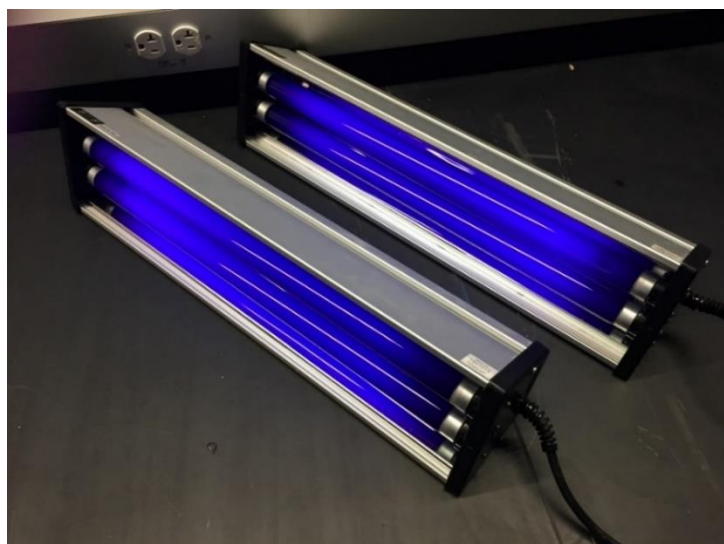
UV-C excimer (222 nm, unfiltered) lamp	Light intensity (mW/cm <sup>2</sup> ) at 185 nm	Light intensity (mW/cm <sup>2</sup> ) at 220 nm	Light intensity (mW/cm <sup>2</sup> ) at 254 nm	Light intensity (mW/cm <sup>2</sup> ) at 365 nm
Treatment 1	-*	<b>1.10</b>	0.16	0.00365
Treatment 2	-	<b>1.36</b>	0.19	0.00445
Treatment 3	-	<b>1.49</b>	0.20	0.0049
Treatment 4	-	<b>1.49</b>	0.19	0.00478
Treatment 5	-	<b>1.41</b>	0.19	0.00455
Treatment 6	-	<b>1.33</b>	0.18	0.00464
Treatment 7	-	<b>1.19</b>	0.19	0.00453
Treatment 8	-	<b>1.04</b>	0.15	0.00407

\*The light intensity is too low to be recorded.

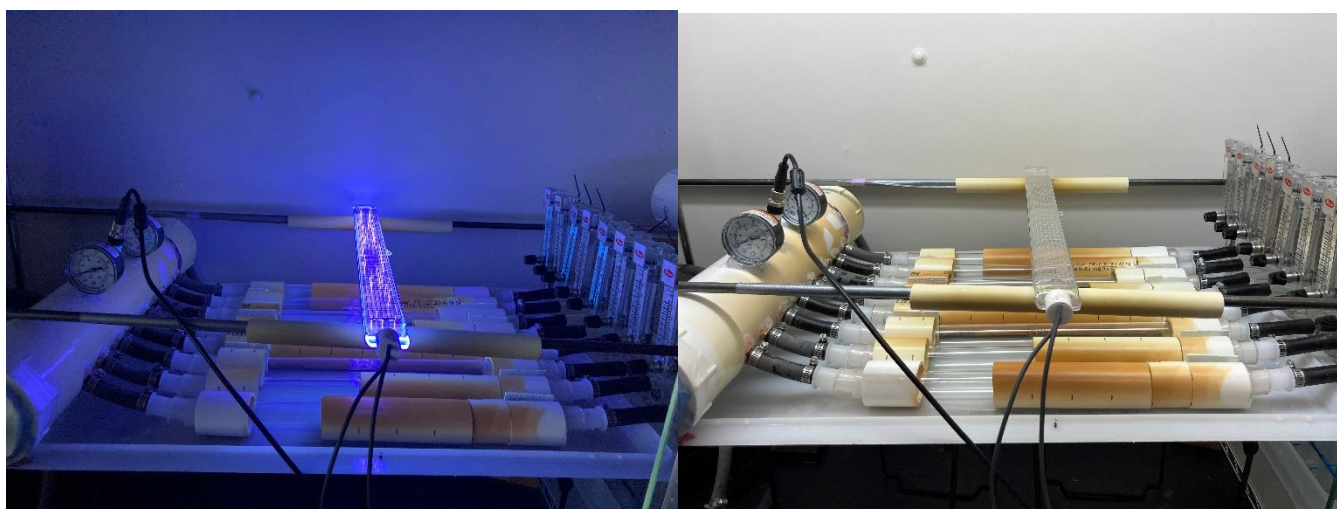
Supplementary Figures S1 – S7 present the UV lamps used in this experiment and an example of light intensity measurement.



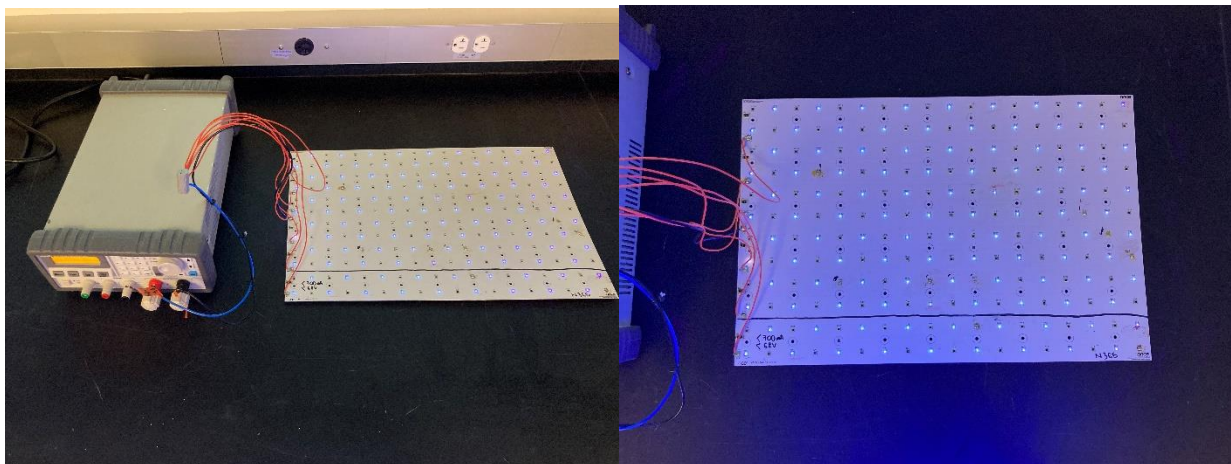
**Supplementary Figure S1.** UV-C (254 nm) germicidal lamps were used in this experiment.



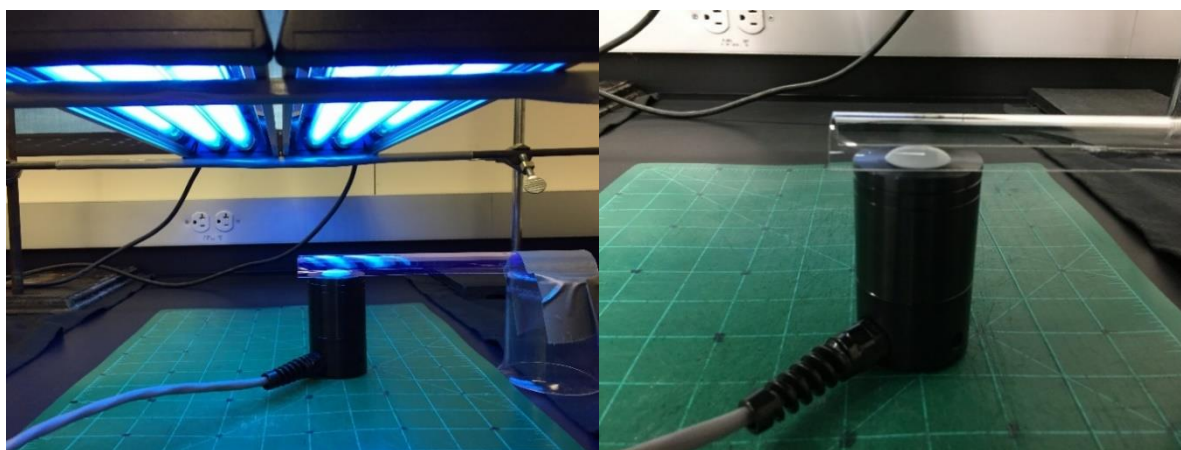
**Supplementary Figure S2.** UV-A (365 nm) fluorescent BLB (blacklight blue) lamps were used in this experiment.



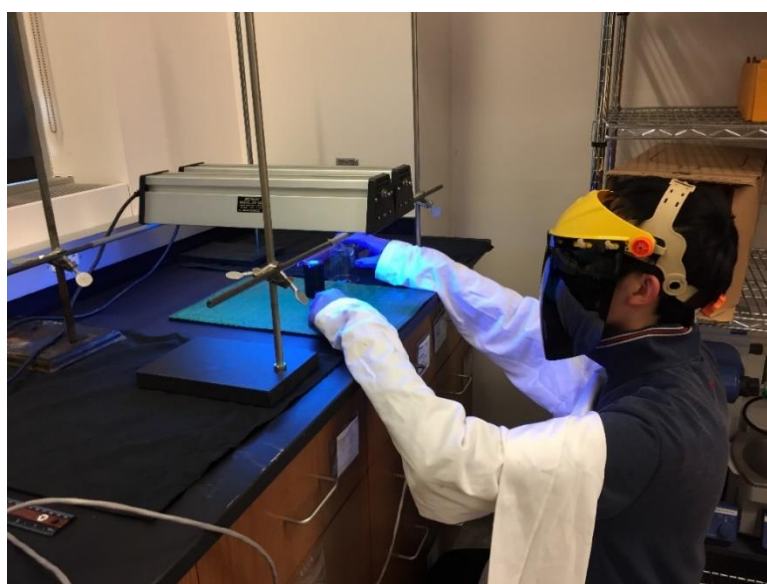
**Supplementary Figure S3.** UV-C (222 nm) excimer lamp was used in this experiment.



**Supplementary Figure S4.** UV-A (365 nm) LED lamp was used in this experiment.



**Supplementary Figure S5.** This figure shows the setup of UV light intensity measurement. A UV sensor probe was covered by a quartz tube's semi-circular shape to simulate the light intensity in the middle plane of the quartz tube.



**Supplementary Figure S6.** This figure shows the setup of UV light intensity (irradiance) measurement. The operator wears a UV-proof face shield while measuring the UV light intensity. Another operator is recording the data from the radiometer screen (not shown in this photo).





**Supplementary Figure S7.** This photo shows the setup to control the UV dose by short sections of PVC shielding the quartz tubes with the PRRSV aerosol from irradiation.

## 2. Techno-economic analysis of applications of UV and HEPA filters on a farm scale

### 2.1. Estimation of UV lamps and HEPA filters

To this date, very few commercial production swine facilities (except some nucleus, boar studs, or sows barn) use HEPA (>MERV 17) filters or other high-grade filters. This estimation is based on a 1000-head swine barn with boar studs and sow.

Assumptions:

- (1) One HEPA filter has a capacity of 600 CFM.
- (2) Labor cost is omitted from the economic analysis as the focus is mainly on electricity and material cost.
- (3) All UV lamps are functioning to the same extent, and the irradiance follows the reverse reciprocal rule.
- (4) Capital and construction cost is not included. However, it is estimated that the installation of air filtration systems on large sow farms is approximately \$150–200 per sow (or approximately \$450,000–600,000 for 3000 sow-herds) as reported by Alonso et al., 2013 [1].

According to MWSP-8 Swine Housing and Equipment Handbook, it is assumed that each breeding sow occupies a solid floor area of 48 ft<sup>2</sup>, and 6 sows are arranged in one pen; each boar takes 60 ft<sup>2</sup>, and only 1 boar lives in one pen. The layout of a 9-pen unit is designed to house 60 breeding sows and 6 boars, occupying a space of 44 ft (13.4 m) by 72 ft (22 m). To accommodate 1000 pigs (910 are sows, 90 are boars, the ratio is calculated following the example provided in the handbook, 15 of such layouts are needed. The resulting dimension of the swine barn is 330 m by 13.4 m (1,080 ft by 44 ft). The height of this barn is assumed to be 2.4 m (8 ft), based on the real dimension of swine barns.

The volume of air in the swine barn at a given time,

$$V_{tot} = l \times w \times h \quad (14)$$

where,  $V_{tot}$  = total volume of air in the swine barn ( $m^3$ ) at any given time

$l$  = length of the barn (m)

$w$  = width of the barn (m)

$h$  = height of the barn (m)

The total ventilation rate needed can be expressed as,

$$Q_n = n \times Q \quad (15)$$

where  $Q_n$  = total ventilation rate needed (CFM or  $m^3$ )  
 $N$  = number of pigs  
 $Q$  = minimum ventilation rate needed per pig

$$\text{Residence time (air exchange time) in the swine barn, } t_r = \frac{V_{tot}}{Q_n} \quad (16)$$

Based on the assumption (1), the total number of HEPA filter needed is  $n = Q_{tot}/600$   
 To achieve a target UV dose, the treatment time needed is (derived from Eqn. 1),

$$t_n = \frac{D}{I} \quad (17)$$

where  $t_n$  = treatment time (s) desired  
 $D$  = dose needed to achieve the target reduction  
 $I$  = light intensity (mW/cm<sup>2</sup>)

For each UV unit (chamber), at any moment, the volume of air underneath it that can be effectively disinfected is,

$$V_{UV} = a \times b \times c \quad (18)$$

where  $V_{UV}$  = volume of air under a UV unit at any given time ( $m^3$ )  
 $a$  = length ( $m$ ) of the effective coverage of each UV unit  
 $b$  = width ( $m$ ) of the effective coverage each UV unit  
 $c$  = distance ( $m$ ) between the UV lamp to the center place and the position of filters (as if they were there)

The residence time refers to the air exchange time within the barn. The treatment time is a fraction of the residence time because it calculates the residence time within the UV-effective range.

$$t_t = \frac{V_{tot}}{Q_n} \quad (19)$$

If  $t_t > t_n$ , then the UV treatment time is higher than what is needed to achieve the target dose.

Supplementary Table 3 shows the estimated cost for the HEPA filtration system. Supplementary Table 4 shows the estimated total cost of implementing HEPA filters.

**Supplementary Table S3.** Estimation of the cost of specific items for HEPA filtration.

Items	Cost (\$)	Comment
HEPA V-bank filters	\$100 each	Include the cost of pre-filters
Maintenance	10% of total	Maintenance for 1 year

**Supplementary Table S4.** Estimation of the cost of implementing HEPA filters in a 1000-head swine barn with different swine types for 1 year.

	Basic information		Ventilation rate (CFM/pig)		Total ventilation rate (CFM)		# of HEPA filters needed		Cost for HEPA filters for 1 year (hot weather)
	Head (unit)	Weight (lb)	Cold weather	Hot weather	Cold weather	Hot weather	Cold weather	Hot weather	
Sows and Litter	910	400	20	500	20,000	500,000	33	833	\$83,333
Boars & Breeding Sows	90	400	14	300	1,260	27,000	2	45	

#### Reference

1. Alonso, C.; Murtaugh, M. P.; Dee, S. A.; Davies, P. R. Epidemiological study of air filtration systems for preventing PRRSV infection in large sow herds. *Preventive Veterinary Medicine* **2013**, 112, 109–117.