Supplementary Material

1. Additional information on UV light measurements

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

**Supplementary Table 1.** Summary of UV light intensities for UVC 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/cm2) at 185 nm | Light intensity (mW/cm2) at 220 nm | Light intensity (mW/cm2) at 254 nm | Light intensity (mW/cm2) at 365 nm |
| Treatment 1 | **-\*** | **-** | **0.11** | 0.02 |
| Treatment 2 | **-** | **-** | **0.14** | 0.03 |
| Treatment 3 | **-** | **-** | **0.15** | 0.03 |
| Treatment 4 | **-** | **-** | **0.16** | 0.03 |
| Treatment 5 | **-** | **-** | **0.16** | 0.03 |
| Treatment 6 | **-** | **-** | **0.15** | 0.03 |
| Treatment 7 | **-** | **-** | **0.13** | 0.02 |
| Treatment 8 | **-** | **-** | **0.10** | 0.02 |

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

**Supplementary Table 2.** Summary of UV light intensities for UV-C excimer (222 nm) measured using a UV radiometer with four different wavelength detector/filter combinations (185 nm, 220 nm, 254 nm, and 365 nm, respectively).

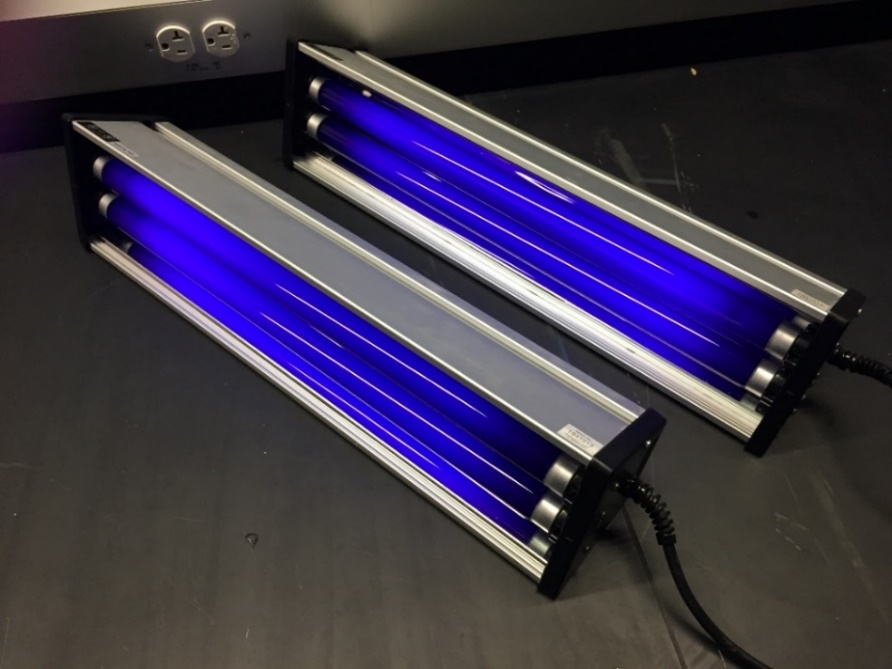
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UV-C excimer (222 nm) lamp | Light intensity (mW/cm2) at 185 nm | Light intensity (mW/cm2) at 220 nm | Light intensity (mW/cm2) at 254 nm | Light intensity (mW/cm2) at 365 nm |
| Treatment 1 | **-\*** | **0.028** | 0.00526 | 0.00365 |
| Treatment 2 | **-** | **0.039** | 0.00566 | 0.00445 |
| Treatment 3 | **-** | **0.041** | 0.00593 | 0.0049 |
| Treatment 4 | **-** | **0.044** | 0.00596 | 0.00478 |
| Treatment 5 | **-** | **0.042** | 0.00575 | 0.00455 |
| Treatment 6 | **-** | **0.043** | 0.00593 | 0.00464 |
| Treatment 7 | **-** | **0.042** | 0.00570 | 0.00453 |
| Treatment 8 | **-** | **0.039** | 0.00515 | 0.00407 |

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

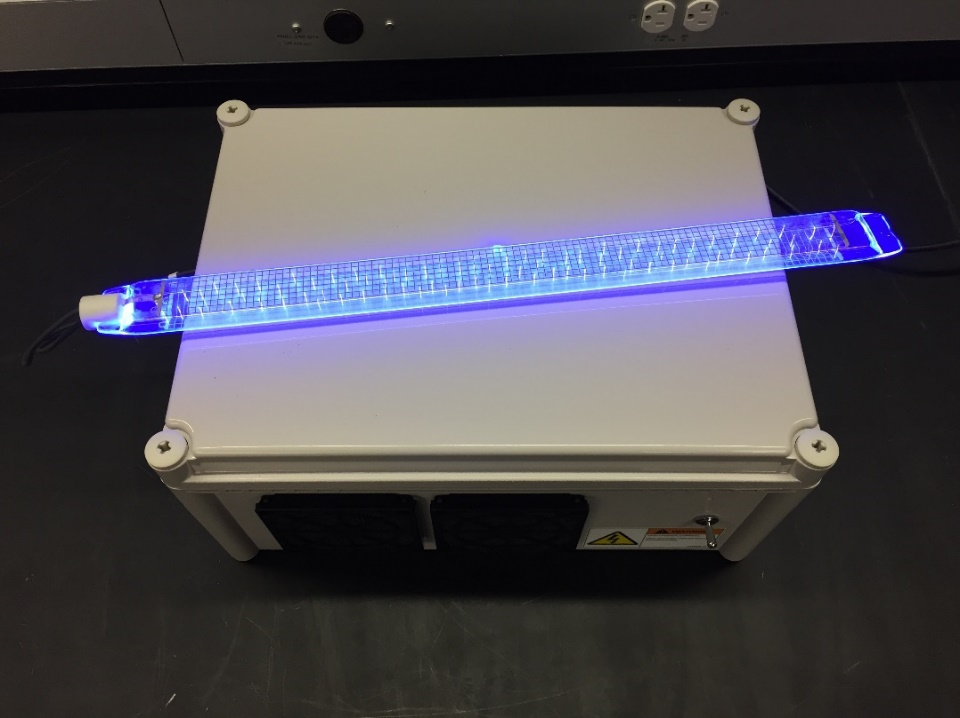
Supplementary Figures S1 – S5 present the UV lamps used in this experiment and an example of light intensity measurement.



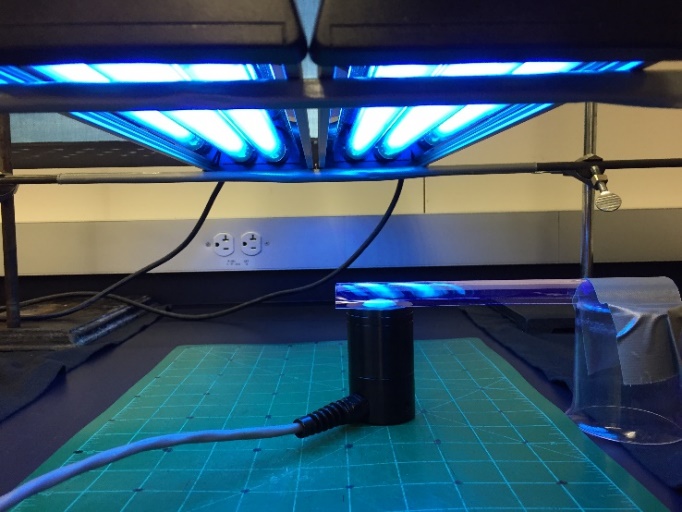
**Supplementary Figure 1.** UV-C (254 nm) germicidal lamps used in this experiment.



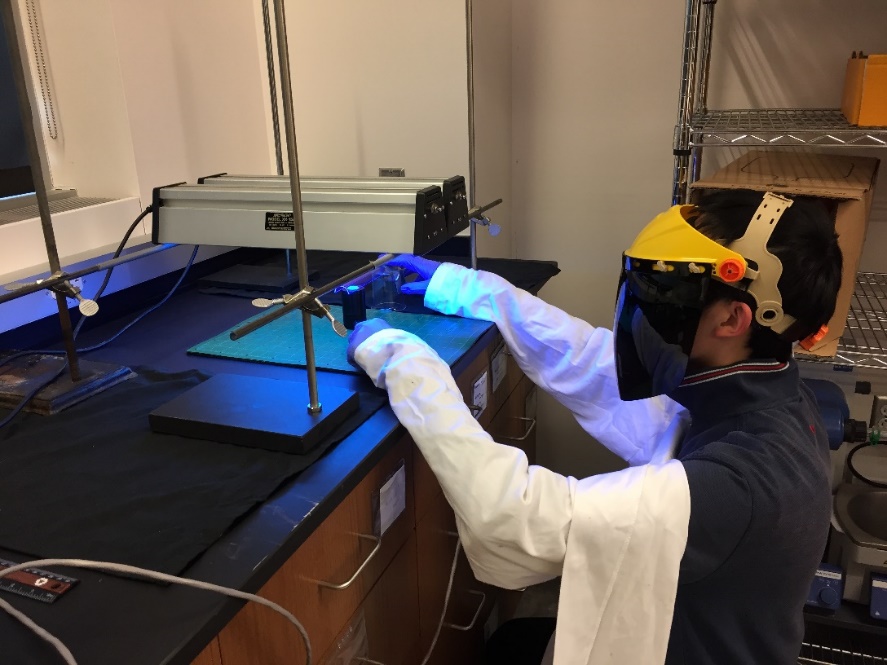
**Supplementary Figure 2.** UV-A (365 nm) fluorescent BLB (blacklight blue) lamps used in this experiment.



**Supplementary Figure 3.** UV-C (222 nm) excimer lamp used in this experiment.



**Supplementary Figure 4.** This figure shows the setup of UV light intensity measurement. A UV sensor probe was covered by a semi-circular shape of quartz tube to simulate the light intensity in the middle plane of the quartz tube.



**Supplementary Figure 5.** 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).

Photo of shielded tubes

**Supplementary Figure 6.** This photo shows the setup to control the UV dose by short sections of PVC shielding the quatz tubes with the PRRSV aerosol from irradiation.

1. **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.

According to MWSP-8 Swine Housing and Equipment Handbook, it is assumed that each breeding sow occupies a solid floor area of 48 ft2, and 6 sows are arranged in one pen; each boar takes 60 ft2, 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,

|  |  |
| --- | --- |
|  | (14) |

where, *Vtot*= total volume of air in the swine barn ( 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,

|  |  |
| --- | --- |
|  | (15) |

where *Qn* = total ventilation rate needed (cfm or )

*N* = number of pigs

*Q* = minimum ventilation rate needed per pig

|  |  |
| --- | --- |
| Residence time (air exchange time) in the swine barn, | (16) |

Based on assumption (1), the total number of HEPA filter needed is

To achieve a target UV dose, the treatment time needed is (derived from Eqn. 1),

|  |  |
| --- | --- |
|  | (17) |

where *tn* = treatment time (s) desired

*D* = dose needed to achieve target reduction

*I* = light intensity (mW/cm2)

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

|  |  |
| --- | --- |
|  | (18) |

where = volume of air under a UV unit at any given time

a = length of the effective coverage of each UV unit

b = width 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.

|  |  |
| --- | --- |
|  | (19) |

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

Supplementary Table 1 shows the estimated cost for the HEPA filtration system. Supplementary Table 2 shows the estimated total cost on implementing HEPA filters.

**Supplementary Table 1.** Estimation of the cost of specific items for HEPA filteration.

|  |  |  |
| --- | --- | --- |
| **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 2.** 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** | |
| Head (unit) | Weight (lb) | Cold weather | Hot weather | Cold weather | Hot weather | Cold weather | Hot weather | Cost for HEPA filters for 1 year (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 |