Correction

Correction: Li et al. Mitigation of Airborne PRRSV Transmission with UV Light Treatment: Proof-of-Concept. Agriculture 2021, 11, 259

Peiyang Li 1, Jacek A. Koziel 1,* 1, Jeffrey J. Zimmerman 1, Jianqi Zhang 2, Ting-Yu Cheng 2, Wannarat Yim-Im 2, William S. Jenks 3, Myeongseong Lee 1, Baitong Chen 1 and Steven J. Hoff 1

1 Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, IA 50011, USA; peiyangl@iastate.edu (P.L.); leefame@iastate.edu (M.L.); baitongc@iastate.edu (B.C.); hoffer@iastate.edu (S.J.H.)
2 Department of Veterinary Diagnostic and Production Animal Medicine, Iowa State University, Ames, IA 50011, USA; jjzimm@iastate.edu (J.J.Z.); jqzhang@iastate.edu (J.Z.); cheng.1784@osu.edu (T.-Y.C.); wyimim@iastate.edu (W.Y.-L.)
3 Department of Chemistry, Iowa State University, Ames, IA 50011, USA; wsjenks@iastate.edu

* Correspondence: koziel@iastate.edu; Tel.: +1-515-294-4206

We would like to make corrections to the original article [1]. We found that UV-C light intensity (irradiance) documented in our paper was incorrect for the 222 and 254 nm wavelengths. The discrepancy was due to unintentional mis-selection of the calibration factors, which must be entered and programmed into the radiometer for each UV wavelength. The 365 nm light intensity was not affected. Therefore, we properly selected the calibrations factors, did the measurements again, and corrected all affected tables, figures, and text. Below is the itemized list of corrections in the order of appearance in the original paper.

1. Abstract—the following passage needs to be corrected:

The original version:
“One-stage and two-stage UV inactivation models estimated the UV doses needed for target percentage (%) reductions on PRRSV titer. UV-C (254 nm) dose needed for 3-log (99.9%) reduction was 0.521 and 0.0943 mJ/cm², respectively, based on one-stage and two-stage models. An order of magnitude lower UV-C (222 nm) doses were needed for a 3-log reduction, i.e., 0.0882 and 0.048 mJ/cm², based on one-stage and two-stage models, respectively.”

The correct version is:
“One-stage and two-stage UV inactivation models estimated the UV doses needed for target percentage (%) reductions on PRRSV titer. UV-C (254 nm) dose needed for 3-log (99.9%) reduction was 19.43 and 2.44 mJ/cm², respectively, based on one-stage and two-stage models. An order of magnitude lower UV-C (222 nm) doses were needed for a 3-log reduction, i.e., 0.0882 and 0.048 mJ/cm², based on one-stage and two-stage models, respectively.”

2. Light intensity in two columns for UV-C (254 nm) and UV-C excimer (222 nm, unfiltered) needs to be corrected in Table 1, i.e., data in the second and the third column, respectively.
The original version:

Table 1. Average UV light intensity for each treatment (quartz tube #) measured without tube shielding. In the experiment, the quartz tubes were covered with different lengths of polyvinyl chloride (PVC) pipes to control the UV dose, and thus, the effective light intensity was estimated for each treatment separately.

| UV Light Intensity (mW/cm$^2$) | UV-C (254 nm) | UV-C (222 nm) | UV-A (365 nm, Fluorescent) | UV-A (365 nm, LED) |
|---------------------------------|---------------|---------------|-----------------------------|--------------------|
| Treatment 1 *                   | 0.11          | 0.028         | 0.57                        | 1.71               |
| Treatment 2                     | 0.14          | 0.039         | 0.70                        | 1.93               |
| Treatment 3                     | 0.15          | 0.041         | 0.77                        | 2.00               |
| Treatment 4                     | 0.16          | 0.044         | 0.80                        | 2.02               |
| Treatment 5                     | 0.16          | 0.042         | 0.79                        | 2.01               |
| Treatment 6                     | 0.15          | 0.043         | 0.74                        | 1.99               |
| Treatment 7                     | 0.13          | 0.042         | 0.66                        | 1.90               |
| Treatment 8                     | 0.10          | 0.039         | 0.49                        | 1.66               |

* Treatment 1 refers to quartz tube 1. The same rule applies to all the treatments.

The corrected Table 1 is:

Table 1. Average UV light intensity for each treatment (quartz tube #) measured without tube shielding. In the experiment, the quartz tubes were covered with different lengths of polyvinyl chloride (PVC) pipes to control the UV dose, and thus, the effective light intensity was estimated for each treatment separately.

| UV Light Intensity (mW/cm$^2$) | UV-C (254 nm) | UV-C (222 nm) | UV-A (365 nm, Fluorescent) | UV-A (365 nm, LED) |
|---------------------------------|---------------|---------------|-----------------------------|--------------------|
| Treatment 1 *                   | 3.43          | 1.10          | 0.57                        | 1.71               |
| Treatment 2                     | 4.40          | 1.36          | 0.70                        | 1.93               |
| Treatment 3                     | 5.04          | 1.49          | 0.77                        | 2.00               |
| Treatment 4                     | 5.35          | 1.49          | 0.80                        | 2.02               |
| Treatment 5                     | 5.35          | 1.41          | 0.79                        | 2.01               |
| Treatment 6                     | 5.06          | 1.33          | 0.74                        | 1.99               |
| Treatment 7                     | 4.53          | 1.19          | 0.66                        | 1.90               |
| Treatment 8                     | 3.57          | 1.04          | 0.49                        | 1.66               |

* Treatment 1 refers to quartz tube 1. The same rule applies to all the treatments.
3. The UV254 dose (mJ/cm², horizontal axis values) in Figure 2 needs to be corrected.

The original Figure 2:

![Original Figure 2](image)

*Figure 2.* UV-C (254 nm) treatment inactivation of aerosolized PRRSV. PRRSV post-UV survival (%) = \( N_t/N_0 \). A log10 normalized PRRSV post-UV survival is shown in Figure A1. One-stage and two-stage inactivation models are marked with dashed and solid lines, respectively.

The corrected Figure 2 is:

![Corrected Figure 2](image)

*Figure 2.* UV-C (254 nm) treatment inactivation of aerosolized PRRSV. PRRSV post-UV survival (%) = \( N_t/N_0 \). A log10 normalized PRRSV post-UV survival is shown in Figure A1. One-stage and two-stage inactivation models are marked with dashed and solid lines, respectively.
4. The UV222 dose (mJ/cm², horizontal axis values) in Figure 3 needs to be corrected.

The original Figure 3:

![Figure 3](image_url)

**Figure 3.** UV-C (222 nm) treatment inactivation of aerosolized PRRSV. PRRSV post-UV survival (% = N_t/N_0. A log_{10} normalized PRRSV post-UV survival is shown in Figure A2. One-stage and two-stage inactivation models are marked with dashed and solid lines, respectively.

The corrected Figure 3 is:

![Figure 3](image_url)

**Figure 3.** UV-C (222 nm) treatment inactivation of aerosolized PRRSV. PRRSV post-UV survival (% = N_t/N_0. A log_{10} normalized PRRSV post-UV survival is shown in Figure A2. One-stage and two-stage inactivation models are marked with dashed and solid lines, respectively.
The model outputs in two columns for UV-C (254 nm) and UV-C (222 nm) need to be corrected in Table 2, i.e., the second and third columns, respectively.

The corrected Table 2 is:

Table 2. One-stage and two-stage models, parameter estimations, and model parameters for inactivation of airborne PRRSV with four types of UV light tested.

| UV Types | Two-stage inactivation model | One-stage inactivation model |
|----------|-----------------------------|-----------------------------|
| Parameters | UV-C (254 nm) | UV-C Excimer (222 nm) | UV-A (365 nm, Fluorescent) | UV-A (365 nm, LED) |
| Intercept | −0.0603 | 0.03226 | 0.012422 | −0.02748 |
| Susceptible virus population fraction (f) | 0.97595 | 0.99945 | 0.57417 | 1.72542 |
| Resistant virus population fraction (1 − f) | 0.02405 | 0.00055 | 0.42583 | −0.72542 |
| Inactivation rate (constant), k₁, for resistant virus population (cm²/mJ) | −1.34467 | −24.1466 | −0.13585 | 0.88296 |
| Inactivation rate (constant), k₂, for susceptible virus population (cm²/mJ) | 15.55614 | 42.39715 | 2.89537 | 0.02075 |
| Lack-of-fit test p-value | p = 0.228 | p = 0.8922 | p = 0.2848 | p = 0.6532 |
| Intercept | −0.4727 | −0.06694 | −0.09103 | 0.08388 |
| Inactivation rate, k (cm²/mJ) | 4.8512 | 33.2674 | 0.01556 | −0.02183 |
| Lack-of-fit test p-value | p = 0.006781 | p = 0.1813 | p = 0.3336 | p = 0.7748 |
6. The model Equations (6)–(9) for UV-C (254 nm) and UV-C (222 nm) need to be updated based on the corrected parameters in Table 2.

The original version:
For UV-C (254 nm) (data shown in Figure 2), one-stage and two-stage, respectively,
\[
\log_{10} \frac{N_t}{N_0} = -4.8512 \cdot D_t - 0.4727 \quad (6)
\]
\[
\log_{10} \frac{N_t}{N_0} = \log_{10} \left[ 0.02405 \cdot 10^{1.3467 \cdot D_t} + 0.97595 \cdot 10^{-15.55614 \cdot D_t} \right] - 0.0603 \quad (7)
\]
For UV-C (222 nm) (data shown in Figure 3), one-stage and two-stage, respectively,
\[
\log_{10} \frac{N_t}{N_0} = -33.2674 \cdot D_t - 0.06694 \quad (8)
\]
\[
\log_{10} \frac{N_t}{N_0} = \log_{10} \left[ 0.00055 \cdot 10^{24.1466 \cdot D_t} + 0.99945 \cdot 10^{-42.39715 \cdot D_t} \right] + 0.03226 \quad (9)
\]

The corrected version is:
For UV-C (254 nm) (data shown in Figure 2), one-stage and two-stage, respectively,
\[
\log_{10} \frac{N_t}{N_0} = -0.1307 \cdot D_t - 0.4601 \quad (6)
\]
\[
\log_{10} \frac{N_t}{N_0} = \log_{10} \left[ 0.9675 \cdot 10^{-0.58947 \cdot D_t} + 0.0325 \cdot 10^{0.01927 \cdot D_t} \right] - 0.02367 \quad (7)
\]
For UV-C (222 nm) (data shown in Figure 3), one-stage and two-stage, respectively,
\[
\log_{10} \frac{N_t}{N_0} = -1.0053 \cdot D_t - 0.1779 \quad (8)
\]
\[
\log_{10} \frac{N_t}{N_0} = \log_{10} \left[ 0.9951 \cdot 10^{-1.9189 \cdot D_t} + 0.0049 \cdot 10^{0.3014 \cdot D_t} \right] + 0.0775 \quad (9)
\]

7. The estimated (projected) UV doses (mJ/cm²) needed for target % aerosolized PRRSV reduction for UV-C (254 nm) and UV-C (222 nm) that are based on the newly corrected models need to be corrected in Table 3, i.e., in the second and third row, respectively.

The original version:

Table 3. Estimated the UV dose (mJ/cm²) needed for target % aerosolized PRRSV reduction in fast-moving air, using both one-stage and two-stage inactivation models.

|                      | 90% (1-log) Reduction | 99% (2-log) Reduction | 99.9% (3-log) Reduction |
|----------------------|------------------------|-----------------------|-------------------------|
|                      | 1-Stage | 2-Stage | 1-Stage | 2-Stage | 1-Stage | 2-Stage |
| UV-C (254 nm)        | 0.109   | 0.0681  | 0.315   | 0.0872  | 0.521 a | 0.0943  |
| UV-C (222 nm)        | 0.0280  | 0.0246  | 0.0581  | 0.0429  | 0.0882  | 0.0483  |
| UV-A (365 nm, fluor.)| 58.42   | -       | 122.684 | -       | 186.952 | -       |
| UV-A (365 nm, LED)   | -49.651 b | 58.285  | -95.460 b | 106.478 | -141.268 b | 154.671 |

a UV-C (254 nm) dose needed to inactivate 99.9% aerosolized PRRSV was estimated to be 1.21 mJ/cm² by Cutler et al., 2012 [22]. b Negative values are not considered biologically meaningful, i.e., the UV light under these categories did not have an inactivation effect for the doses used in the experiment.
The corrected Table 3 is:

Table 3. Estimated the UV dose (mJ/cm$^2$) needed for target % aerosolized PRRSV reduction in fast-moving air, using both one-stage and two-stage inactivation models.

|                      | 90% (1-log) Reduction | 99% (2-log) Reduction | 99.9% (3-log) Reduction |
|----------------------|-----------------------|------------------------|-------------------------|
|                      | 1-Stage | 2-Stage | 1-Stage | 2-Stage | 1-Stage | 2-Stage |
| UV-C (254 nm)        | 4.131  | 1.933   | 11.782 | 2.662   | 19.433  | 2.442   |
| UV-C (222 nm)        | 0.818  | 0.581   | 1.812  | 1.036   | 2.807   | 1.044   |
| UV-A (365 nm, fluor.)| 58.42  | -       | 122.684| -       | 186.952 | -       |
| UV-A (365 nm, LED)   | -58.285| 58.285  | -95.460| 106.478 | -141.268| 154.671 |

$^a$ UV-C (254 nm) dose needed to inactivate 99.9% aerosolized PRRSV was estimated to be 1.21 mJ/cm$^2$ by Cutler et al., 2012 [22]. $^b$ Negative values are not considered biologically meaningful, i.e., the UV light under these categories did not have an inactivation effect for the doses used in the experiment.

8. The following two passages in Discussion Section 4.1 need to be corrected.

The original version:
“This research showed that the UV chamber achieve up to ~2-log reduction in aerosolized PRRSV with a UV dose <0.3 mJ/cm$^2$ (UV-C, 254 nm), or <0.08 mJ/cm$^2$ (UV-C, 222 nm), under experimental conditions.”

The correct version is:
“This research showed that this UV chamber achieved ~2-log reduction in aerosolized PRRSV with a UV dose <5 mJ/cm$^2$ (UV-C, 254 nm), or <2 mJ/cm$^2$ (UV-C, 222 nm), under experimental conditions.”

The original version:
“The experimental data were evaluated using both one-stage and two-stage fit with inactivation models for all four types of UV light used in this experiment. The two-stage model provided a better fit with both UV-C 254 nm and UV-C 222 nm, with lack-of-fit $p$-values of 0.228 and 0.892 (both >0.1), respectively. Due to the magnitude difference of doses needed for 3-log reduction between one-stage and two-stage models, 0.521 and 0.0943 mJ/cm$^2$, respectively, we reported both values for consideration, but 0.521 mJ/cm$^2$ is more realistic and similar to the dose 1.21 mJ/cm$^2$ reported by Cutler et al. (2012) [22]. The estimated UV-C (222 nm) doses were similar between one-stage and two-stage models.”

The correct version is:
“The experimental data were evaluated using both one-stage and two-stage fit with inactivation models for all four types of UV light used in this experiment. The two-stage model provided a better fit with both UV-C 254 nm and UV-C 222 nm, with lack-of-fit $p$-values of 0.8488 and 0.6565, respectively. Due to the magnitude difference of doses needed for 3-log reduction between one-stage and two-stage models for 254 nm, 19.43 and 2.44 mJ/cm$^2$, respectively, we reported both values for consideration, but 2.44 mJ/cm$^2$ is more realistic and similar to the dose 1.21 mJ/cm$^2$ reported by Cutler et al. (2012) [22]. The estimated UV-C (222 nm) dose was 2.81 and 1.04 mJ/cm$^2$ for the one-stage model and the two-stage model, respectively.”

9. The following statement in Conclusions needs to be corrected. The correction does not change the essential message of the Conclusions in the original paper, i.e., it is a reminder to readers about the actual UV doses reported in the Results.

The original version:
“The results show that UV-C (254 nm) and UV-C excimer (222 nm) effectively inactivated aerosolized PRRSV up to 99% (2-log) with a dose < 0.3 mJ/cm$^2$ for UV-C (254 nm) dose, or <0.08 mJ/cm$^2$ for UV-C (222 nm).”
The correct version is:
“The results show that UV-C (254 nm) and UV-C excimer (222 nm) effectively inactivated aerosolized PRRSV ~99% (2-log) with a dose <5 mJ/cm² for UV-C (254 nm) dose, or <2 mJ/cm² for UV-C (222 nm).”

10. Raw data published in the Supplementary Materials was corrected (‘Corrections—Supplementary Material.pdf’), specifically for the UV-C 254 nm and UV-C 222 nm (Tables S1 and S2).

The original version:

Supplementary Materials: The following are available online at https://www.mdpi.com/2077-0472/11/3/259/s1.

The correct version is:

Data Availability Statement: The raw data are available in a spreadsheet (UV dose vs. PRRSV titer.xlsx).

The original version:

Data Availability Statement: The raw data are available in a spreadsheet (UV dose vs. PRRSV titer.xlsx), which is accessible at Supplementary Materials.

The correct version is:

Data Availability Statement: The raw data are available in a spreadsheet (UV dose vs. PRRSV titer corrected.xlsx), which is accessible at Supplementary Materials.

12. Changes in Acknowledgments

The correct version is:

Acknowledgments: The authors are very thankful to Holger Claus and Ryan Olsen (Ushio America Inc.) for pointing out the discrepancy in reported UV-C 254 nm and 222 nm lamp outputs that led us to investigate, find the source of discrepancy, and correct the manuscript.

13. In Appendix A, the UV254 dose (mJ/cm², horizontal axis values) in Figure A1 needs to be corrected.

The original version:

Figure A1. UV-C (254 nm) treatment inactivation curve on aerosolized PRRSV. One-stage (dashed line) and two-stage (solid line) inactivation curves were drawn. PRRSV survival is expressed as log₁₀(Nt/N0), not as a percentage (%) as shown in Figure 2.
The corrected Figure A1 is:

**Figure A1.** UV-C (254 nm) treatment inactivation curve on aerosolized PRRSV. One-stage (dashed line) and two-stage (solid line) inactivation curves were drawn. PRRSV survival is expressed as $\log_{10}(N_t/N_0)$, not as a percentage (%) as shown in Figure 2.

In Appendix A, the UV222 dose (mJ/cm$^2$, horizontal axis values) in Figure A2 needs to be corrected.

The original version:

**Figure A2.** UV-C (222 nm) treatment inactivation curve on aerosolized PRRSV. One-stage (dashed line) and two-stage (solid line) inactivation curves were drawn. PRRSV survival is expressed as $\log_{10}(N_t/N_0)$, not as a percentage (%) as shown in Figure 3.
The corrected Figure A2 is:

![Graph](image)

**Figure A2.** UV-C (222 nm) treatment inactivation curve on aerosolized PRRSV. One-stage (dashed line) and two-stage (solid line) inactivation curves were drawn. PRRSV survival is expressed as $\log_{10}(N_t/N_0)$, not as a percentage (%) as shown in Figure 3.

In Appendix B, the light intensity for UV-C (254 nm) in Figure A5 needs to be corrected. The original version:

| Treatment | 0.09 | 0.12 | 0.12 | 0.13 | 0.13 | 0.11 | 0.09 |
|-----------|------|------|------|------|------|------|------|
| Treatment 1 | 0.09 | 0.14 | 0.15 | 0.16 | 0.16 | 0.14 | 0.11 |
| Treatment 2 | 0.10 | 0.15 | 0.16 | 0.18 | 0.18 | 0.15 | 0.12 |
| Treatment 3 | 0.11 | 0.17 | 0.18 | 0.19 | 0.19 | 0.16 | 0.12 |
| Treatment 4 | 0.10 | 0.16 | 0.17 | 0.19 | 0.19 | 0.17 | 0.13 |
| Treatment 5 | 0.11 | 0.15 | 0.17 | 0.18 | 0.18 | 0.16 | 0.12 |
| Treatment 6 | 0.09 | 0.14 | 0.14 | 0.15 | 0.15 | 0.14 | 0.10 |
| Treatment 7 | 0.07 | 0.11 | 0.12 | 0.12 | 0.12 | 0.10 | 0.08 |

**Figure A5.** Map of UV light intensity (irradiance) measurements for UV–C (254 nm) for Treatment 1 to Treatment 8. Each colored grid represents an approximately ~4 × 4 cm area where the UV sensor was in place for measurement. The color gradient green–yellow–red represents increasing UV light intensity. Units: mW/cm².
The corrected Figure A5 is:

| Treatment 1 | 2.86 | 3.27 | 4.05 | 4.21 | 4.11 | 3.12 | 2.59 |
|-------------|------|------|------|------|------|------|------|
| Treatment 2 | 3.41 | 4.13 | 5.39 | 5.19 | 5.20 | 4.09 | 3.37 |
| Treatment 3 | 3.84 | 4.75 | 6.01 | 5.98 | 6.03 | 4.76 | 3.92 |
| Treatment 4 | 3.99 | 5.00 | 6.37 | 6.29 | 6.53 | 5.11 | 4.13 |
| Treatment 5 | 3.89 | 4.91 | 6.37 | 6.36 | 6.55 | 5.14 | 4.25 |
| Treatment 6 | 3.66 | 4.66 | 6.02 | 5.99 | 6.13 | 4.86 | 4.09 |
| Treatment 7 | 3.25 | 4.15 | 5.39 | 5.36 | 5.49 | 4.40 | 3.65 |
| Treatment 8 | 2.45 | 3.36 | 4.41 | 4.28 | 4.26 | 3.33 | 2.92 |

**Figure A5.** Map of UV light intensity (irradiance) measurements for UV–C (254 nm) for Treatment 1 to Treatment 8. Each colored grid represents an approximately ~4 × 4 cm area where the UV sensor was in place for measurement. The color gradient green–yellow–red represents increasing UV light intensity. Units: mW/cm².

In Appendix B, the light intensity for UV-C (222 nm) in Figure A6 needs to be corrected.

The original version:

| Treatment 1 | 0.023 | 0.030 | 0.038 | 0.040 | 0.030 | 0.021 | 0.015 |
|-------------|-------|-------|-------|-------|-------|-------|-------|
| Treatment 2 | 0.027 | 0.045 | 0.056 | 0.056 | 0.044 | 0.027 | 0.020 |
| Treatment 3 | 0.030 | 0.046 | 0.058 | 0.058 | 0.047 | 0.027 | 0.020 |
| Treatment 4 | 0.035 | 0.047 | 0.060 | 0.061 | 0.049 | 0.030 | 0.022 |
| Treatment 5 | 0.032 | 0.046 | 0.060 | 0.060 | 0.047 | 0.030 | 0.022 |
| Treatment 6 | 0.032 | 0.048 | 0.061 | 0.060 | 0.049 | 0.031 | 0.021 |
| Treatment 7 | 0.033 | 0.047 | 0.060 | 0.059 | 0.047 | 0.031 | 0.021 |
| Treatment 8 | 0.029 | 0.044 | 0.057 | 0.055 | 0.043 | 0.029 | 0.018 |

**Figure A6.** Map of UV light intensity (irradiance) measurements for UV-C (222 nm) for Treatment 1 to Treatment 8. The color gradient green–yellow–red represents increasing UV light intensity. Units: mW/cm².
The corrected Figure A6 is:

![Figure A6](image)

**Figure A6.** Map of UV light intensity (irradiance) measurements for UV-C (222 nm) for Treatment 1 to Treatment 8. The color gradient green–yellow–red represents increasing UV light intensity. Units: mW/cm².

The authors apologize for any inconvenience caused. This correction was approved by the Academic Editor. The original publication has also been updated.

Reference

1. Li, P.; Koziel, J.A.; Zimmerman, J.J.; Zhang, J.; Cheng, T.-Y.; Yim-Im, W.; Jenks, W.S.; Lee, M.; Chen, B.; Hoff, S.J. Mitigation of Airborne PRRSV Transmission with UV Light Treatment: Proof-of-Concept. *Agriculture* 2021, 11, 259. [CrossRef]