# MICROBIOLOGY REPORT

LMS
TECHNOLOGIES,
INC.

6423 Cecilia Circle
Bloomington, MN 55439 USA

Tel: 952-918-9060
Fax: 952-918-9061

Date: June 3, 2021
Test Requested By: Dust Free
Test Type: Multi-Pass Efficiency

**Scope**
Customer provides an Active Air unit and an Air Knight unit for multi-pass efficiency testing with MS-2 bacteriophage (ATCC 15597-B1) as the challenge aerosol contaminants. Testing was performed in a large (1000 $ft^3$) stainless-steel chamber.

**Method**
The MS-2 bacteriophage was harvested and titrated to 1E9 pfu/ml. Suspensions of the organisms were then aerosolized into the chamber using a nebulizer prior to powering the test device. The test chamber air was sampled at 5-minute intervals using a SKC BioStage cascade impactor for 1-minute sampling periods. The cascade impactors were calibrated to an airflow rate of 28.3 liters/min and the sampling inlet was situated at the midpoint of the test chambers. The recovered organisms were enumerated after 24-hours of incubation.

**Air Cleaner Information**
Test Requester: Dust Free
Product Name: Active Air and Air Knight

**Test Conditions**
Environmental Conditions: 72 °F and 50% RH

Microbiologists
John Cherne, James Cherne, Autumn Stivers-Biscuso

Testing Approval
Al Vatine, CEO

**Equipment**
1000 $ft^3$ Stainless-Steel Test Chamber
SKC BioStage Single-Stage Impactors
TSI Scanning Mobility Particle Sizer (SMPS) 3938

**Figure 1. Test chamber**


**Figure 2. Active Air unit**


**Figure 3. Air Knight unit**

## MS-2 Removal Efficiency Formula

The corrected removal efficiencies for both units uses the natural decay data from time=0 as follows:

$$Corrected\ Removal\ Efficiency = 1 - \left(\frac{DevicePFU_{t=x}}{DevicePFU_{t=0}} * \frac{EmptyPFU_{t=0}}{EmptyPFU_{t=x}}\right) \qquad \text{(Equation 1)}$$

**Table 1. MS-2 PFU Removal Efficiency Results (Average of 3 Samples)**

| | Positive-Hole Corrected MS-2 PFU | | |
|---|---|---|---|
| Time (min) | Natural Decay | Active Air | Removal Efficiencies % |
| 0 | 664.3 | 691.5 | N/A |
| 5 | 562.6 | 414.2 | 29.3 |
| 10 | 512.8 | 304.2 | 43.0 |
| 15 | 481.6 | 233.7 | 53.4 |
| 20 | 523.8 | 128.6 | 71.0 |
| 30 | 354.2 | 63.8 | 82.7 |
| 45 | 173.8 | 34.4 | 81.0 |
| 60 | 154.2 | 13.2 | 91.8 |

Microbiologists
John Cherne, James Cherne, Autumn Stivers-Biscuso

Testing Approval
Al Vatine, CEO

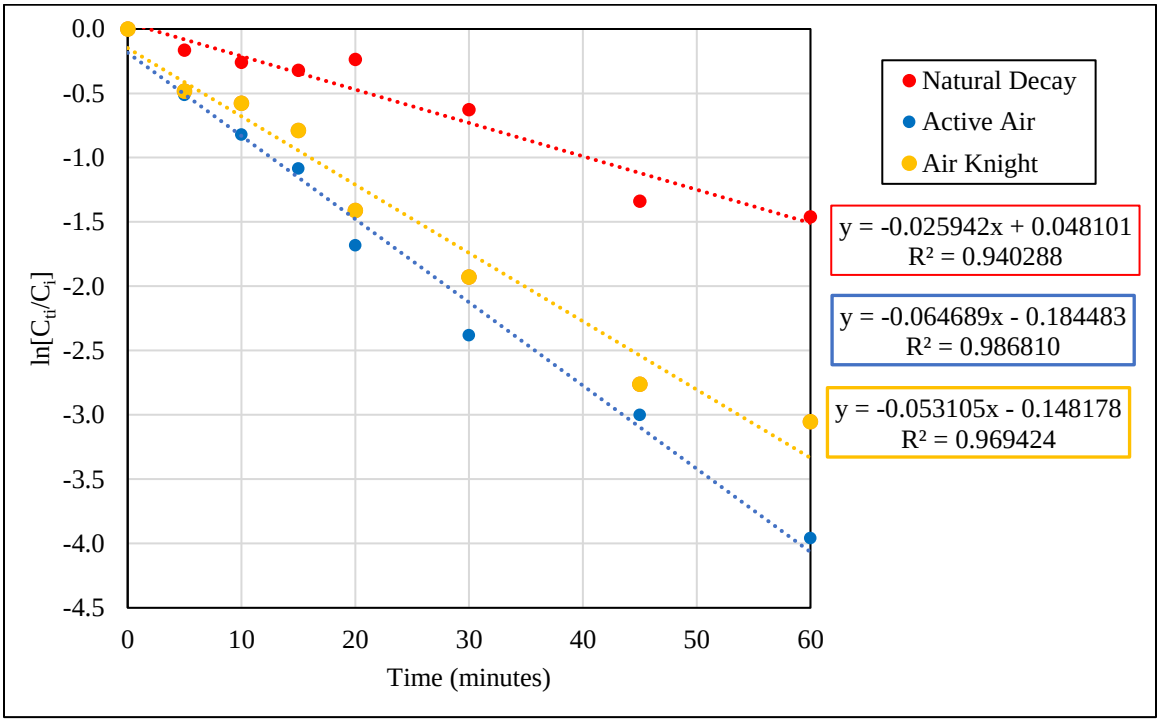
| | Positive-Hole Corrected MS-2 PFU | | |
|---|---|---|---|
| Time (min) | Natural Decay | Air Knight | Removal Efficiencies % |
| 0 | 664.3 | 614.8 | N/A |
| 5 | 562.6 | 379.2 | 27.2 |
| 10 | 512.8 | 344.6 | 27.4 |
| 15 | 481.6 | 279.3 | 37.3 |
| 20 | 523.8 | 149.9 | 69.1 |
| 30 | 354.2 | 89.2 | 72.8 |
| 45 | 173.8 | 38.8 | 75.9 |
| 60 | 154.2 | 29 | 79.7 |

These results are plotted in the following graph. MS-2 PFU losses follow the exponential decay function:

$$C_{t_i} = C_i e^{-kt_i} \qquad \text{(Equation 2)}$$

where $C_{ti}$ is the PFU at time $t_i$, $C_i$ is the PFU at time = 0 minutes, $k$ is the decay rate constant, and $t_i$ is the time. The decay rate constant is then found from the slope of the $\ln[C_{ti}/C_i]$ vs. $t_i$ curve:

$$\ln \frac{C_{t_i}}{C_i} = -kt_i + b \qquad \text{(Equation 3)}$$





Microbiologists
John Cherne, James Cherne, Autumn Stivers-Biscuso

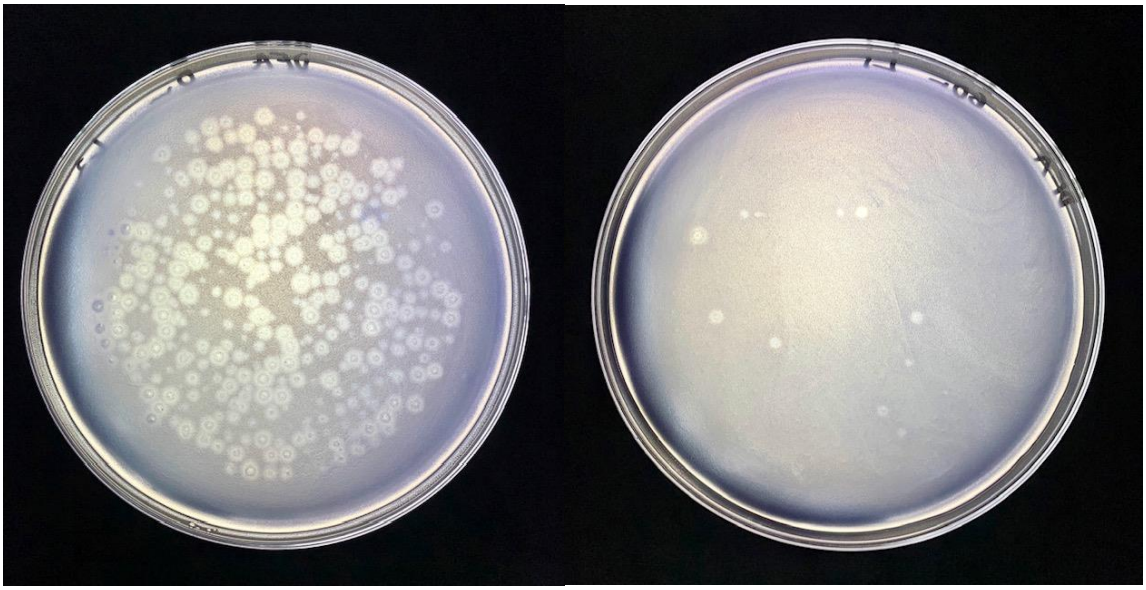
Testing Approval
Al Vatine, CEO

Using Equation 4, the CADR $_{\text{virus}}$ calculation based on cumulative viral particle number concentration is as follows:

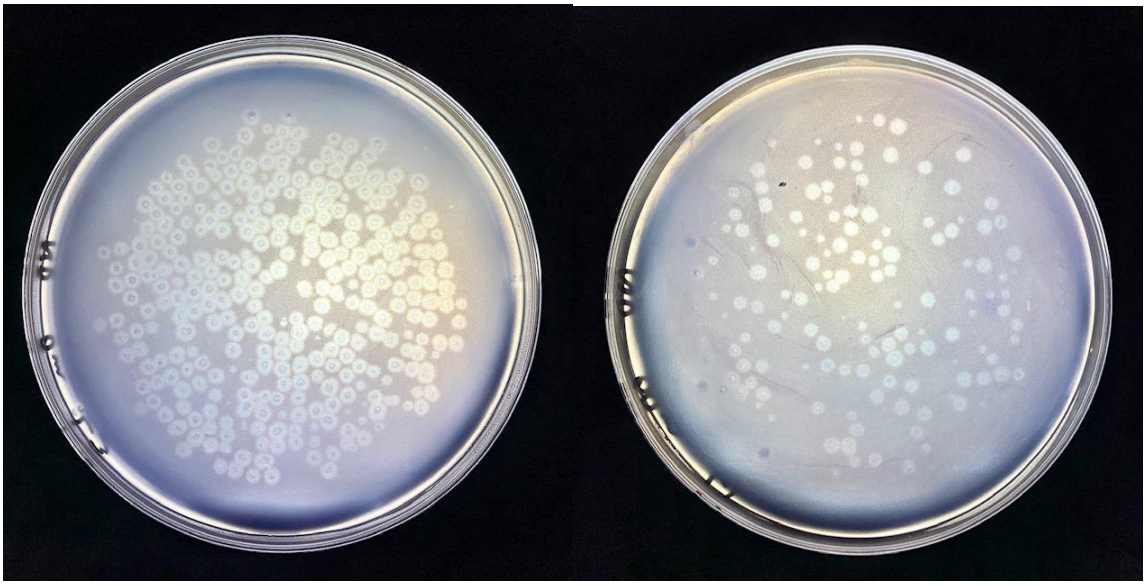
$$CADR = V\left(k_{device} - k_{natural\_decay}\right) \qquad \text{(Equation 4)}$$

$$CADR_{viral\ count} = 1000ft^3(0.064689 - 0.025942) = 38.7\ cfm \qquad \text{(Active Air)}$$

$$CADR_{Viral\ count} = 1000ft^3(0.053105 - 0.025942) = 27.2\ cfm \qquad \text{(Air Knight)}$$



MS-2 with Active Air Unit at 0 time and 60 minutes



Natural Decay of MS-2 at 0 time and 60 minutes

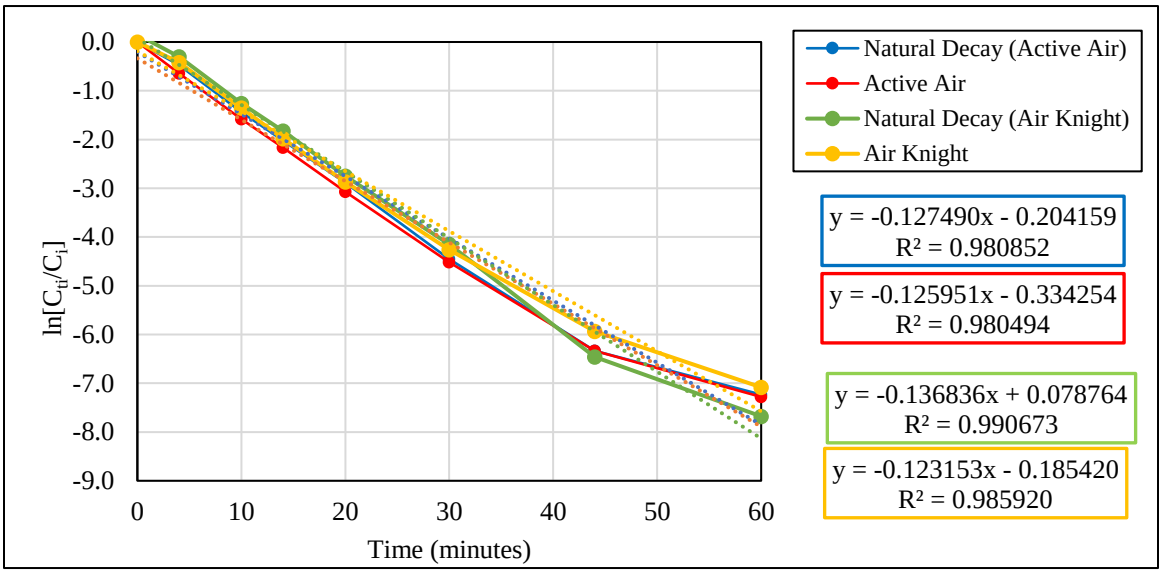
Microbiologists
John Cherne, James Cherne, Autumn Stivers-Biscuso

Testing Approval
Al Vatine, CEO

**SMPS Results**

Cumulative viral particle number concentrations in the range of 16.5nm-604.3nm were measured with the TSI SMPS for both the natural decay test and the two tests (Active air, and Air Knight). As above, particle losses follow the exponential decay function (Equation 2) where $C_{ti}$ is the cumulative viral particle number concentration at time $t_i$, $C_i$ is the cumulative viral particle number concentration at time = 0 minutes, $k$ is the decay rate constant, and $t_i$ is the time.

The curve $\ln[C_{ti}/C_i]$ vs. $t_i$ was plotted to determine the decay rate constants.




**$\ln[C_{ti}/C_i]$ versus time for Natural Decay and Active Air and Air Knight Tests using TSI SMPS viral particle number concentration**

Using Equation 4, the CADR calculation based on cumulative particle number concentration from the TSI SMPS data is as follows:

$$CADR_{particulate} = 1000ft^3(0.125951 - 0.127490) = -1.5\ cfm \quad \text{(Active Air)}$$

$$CADR_{particulate} = 1000ft^3(0.123153 - 0.136836) = -13.7\ cfm \quad \text{(Air Knight)}$$

Conclusion:

The ozone and voc levels were very low and will be reported separately. The difference for
R-CADR for biological sample vs. Viral particle counts indicates deactivation.

Microbiologists
John Cherne, James Cherne, Autumn Stivers-Biscuso

Testing Approval
Al Vatine, CEO