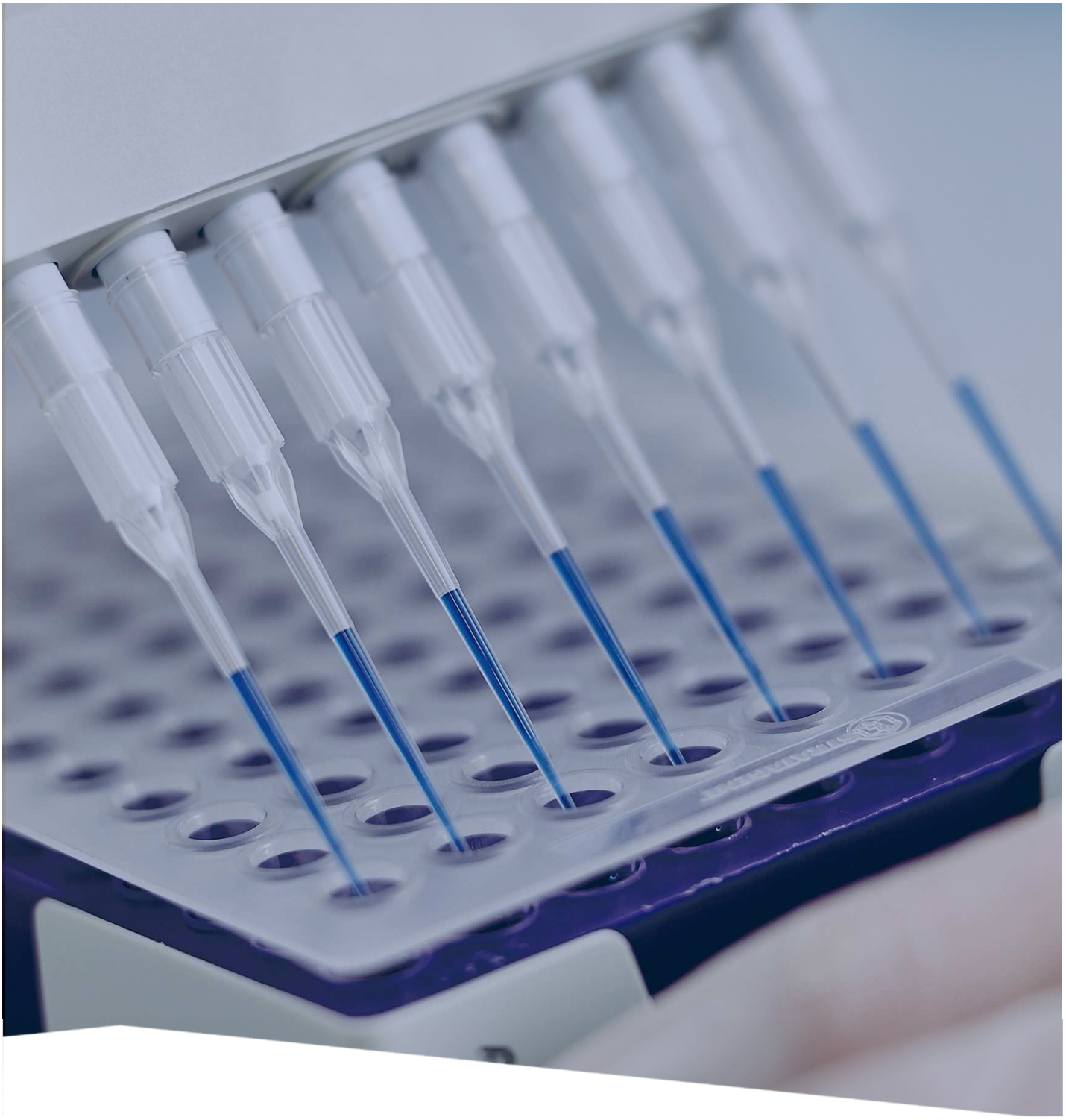

Report no. 933322

Inactivation of aerosolized vira: MS2 bacteriophages

Jimco MAC500

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Inactivation of aerosolized vira: MS2 bacteriophages

Jimco MAC500

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September 2020
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Summary

The purpose of the test is to determine the efficiency of the air purifier to reduce the concentration active of aerosolized MS2 bacteriophages using a modified ISO 16000-36:2018 method. The tested air purifier is a Jimco MAC500.

The significant and consistent difference between the Natural decay test and the Product test clearly shows a reduction of the concentration of active and airborne MS2 caused by the air purifier.

The measured decay of the concentration of active MS2 during the tests is attributed to a natural decay of the aerosol and an attribution of the air purifier. The determined attribution of the air purifier is 0.73-1.2 log-reduction (base 10) per hour in the 20 m^3 room.

According to Kowalski* and Walker† the UV-susceptibility for bacteriophage MS2 is lower than the UV-susceptibility for the enveloped virus, vaccinia virus. Hence, the indicated efficacy of the tested MAC500 UV-C device to degrade the bacteriophage MS2 will be at least similar to the efficacy against enveloped vaccinia virus.
Efficacy against vaccinia virus allows for a claim for efficacy against all enveloped viruses (e.g. MERS-CoV, SARS-CoV-1 and SARS-CoV-2) according to DS/EN 14885:2018.

* Kowalski W. Ultraviolet Germicidal irradiation Handbook. Springer 2009
† Walker and Ko, ENVIRONMENTAL SCIENCE & TECHNOLOGY / VOL. 41, NO. 15, 2007

Method and Materials

The purpose of this test is to determine the inactivation effect of the air purifier on MS2 bacteriophages aerosolized in a test chamber. The natural decay rate of the concentration of active aerosolized MS2 is determined by sampling the air in the chamber over a 2-hour period and the enhanced decay rate due to the air purifier is determined in a similar manner.

The volume of the used chamber is 20 m^3 and it has an inert FEP lining for chemical resistance and easy cleaning. The room is airtight, and a fan is in the room to mix the air and secure a homogenous concentration of aerosols. The aerosol is generated within the room using a nebulizer (Palas AGK 2000) and the air purifier is placed on a stainless-steel table in the middle of the room with a height of about 100cm. See the setup in Figure 1.
The room is cleaned using a 10 ppm ozone system and it is heavily ventilated using clean air for more than 48 hours before the test. The air purifier is turned on more than 24 before the test and a slight overpressure is applied to keep the room clean and reduce build-up of ozone from the device. The ozone concentration before and during the test was below the health exposure limit of 0.1 ppm.
The relative humidity adjusted to 60 +/- 5 %RH and temperature is 22.5 °C +/- 0.5 °C

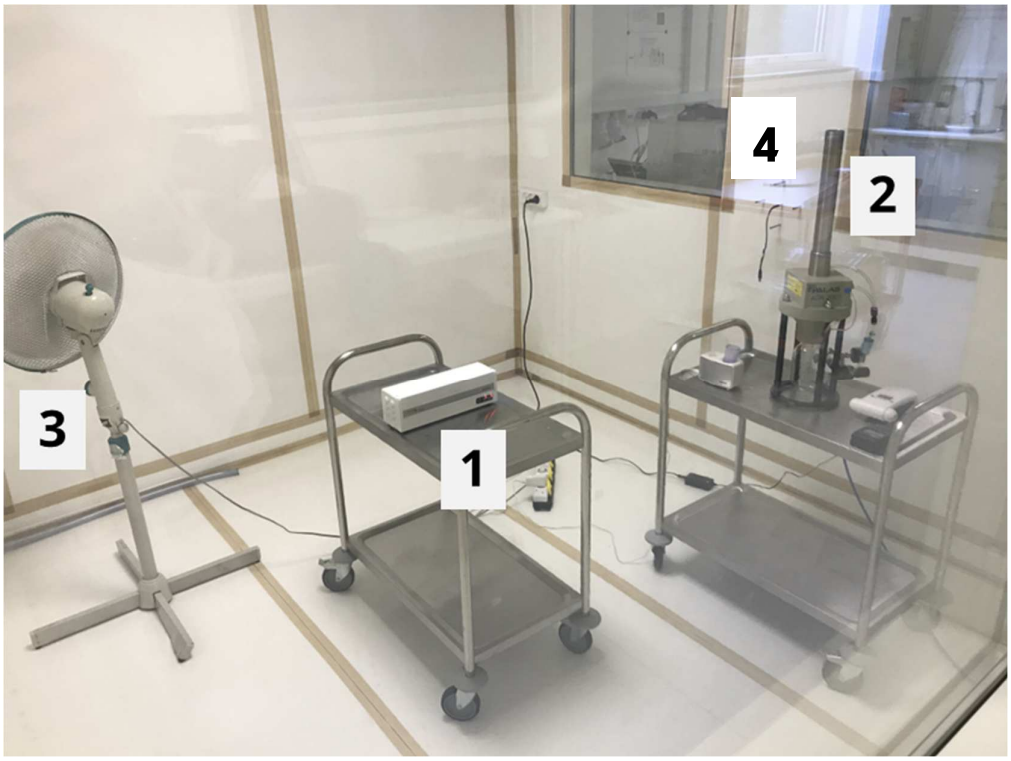

Figure 1: Test chamber. 1: Air Purifier MAC500. 2: Nebulizer (PALAS AGK 2000). 3: Mixing Fan, 4: Sampling port

The sampling of the air is done through a 6mm stainless steel tube in the sidewall of the room using GilAir plus pump at 4 L/min. A total of 20L is extracted per sample into an impinger with 60mL SM-buffer. The timing of sampling is: 0, 15, 30, 60, 120 minutes after finishing aerosolization. The start of the first sample (t = 0 minutes) is less than a minute after the nebulizer is stopped.

The procedure is the following:

1. A suspension of MS2 in SM-buffer is prepared and the concentration is determined.
2. A background sample is taken before the test and injection of aerosol.
3. The air purifier is running during injection of the MS2 containing aerosol based on a suspension of $8 \cdot 10^9$ PFU*/ml. The Palas nebulizer is working at 3.2 bar pressure for a total time of 15 minutes.
4. The sampling is carried out according to the timing plan.
5. After the 2 hours test with the air purifier on, the device is turned off and the room is flushed with clean air for 40 minutes. The particle count is checked to ensure that it is reduced to background level.
6. A reference test of the natural decay is carried out by the same procedure as the above described test but without the air purifier turned on.
7. The sampling is carried out according to the timing plan.
8. The concentration of active MS2 is evaluated for each sample by mixing dilutions series with a fresh culture of the host bacteria, cultivation, and enumeration of PFU following incubation.

The test date is the 23/9 2020 and the plates are counted 24/9 and 25/9 2020.

*PFU is Plague forming units

Microbiological Test Parameters:

Test organism:	MS2 bacteriophage, ATCC 15597-B1
Host organism:	*Escherichia coli*, ATCC 15597
Growth conditions:	Coliform top agar at 37±1°C for 48 hours
Sampling and dilution solution:	SM-buffer

Results

The concentration of active MS2 expressed as PFU/m^3 is shown in Table 1 and in graph in Figure 2. The room background is measured before the first injection of aerosols.

Time	Natural decay	Product test
Minutes	PFU/m^3	PFU/m^3
Background		0
0	6.85E+06	3.86E+06
15	4.22E+06	1.21E+06
30	5.46E+05	1.77E+05
60	9.64E+04	3.22E+03
120	6.07E+03	*

Table 1: The concentration of active MS2 (PFU/m3) for the Natural decay and the Product test. *The Product test sample at 120 minutes is below the detection limit which is determined to be 1.5E+03 PFU/m^3.

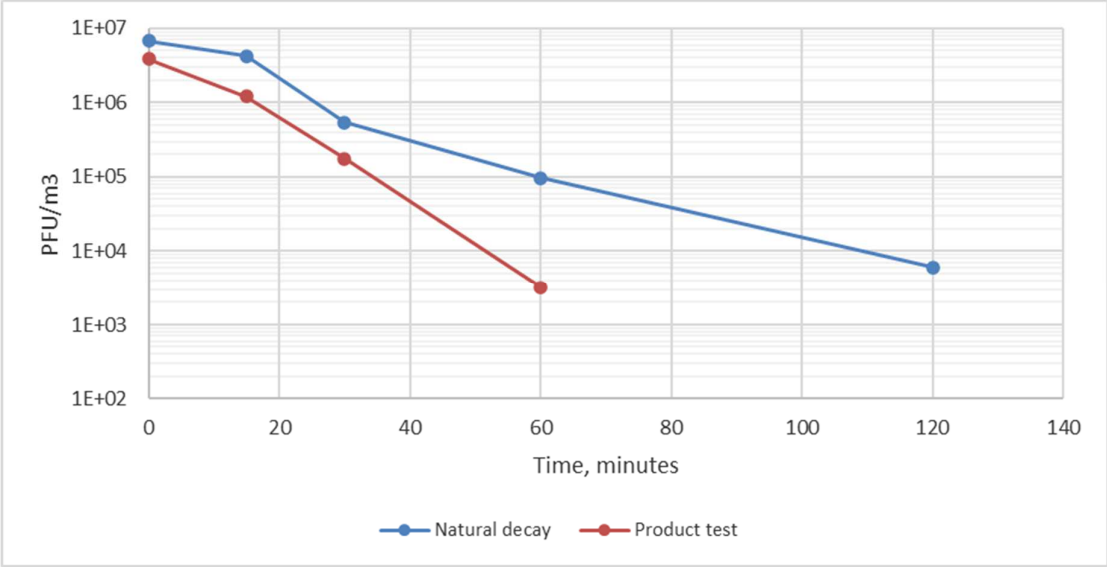

Figure 2: The concentration of active MS2 for the Natural decay and for the Product test

The air purifier's attribution to the overall decay of concentration of MS2 is calculated by the difference in decay constant (k) from the exponential fit to both the Natural decay and the Product test decay:

$$Active\ MS2\ [PFU/m^3] = a \cdot \exp[-k \cdot time]$$

The decay constants are shown in the fits in Figure 3 and summarized in Table 2. The points at 120 minutes have been removed because of larger uncertainties close to the detection limit. The Product attribution is calculated by subtracting the decay constant of the Product test and the Natural decay.

Table 2: Decay constant and corresponding half time and Log-reduction (base 10) per hour.

	Decay constant, min^-1	Half time, min	Log-reduction per hour
Natural decay	0.075	9.24	1.95
Product test	0.121	5.73	3.15
Product attribution	0.046	15.07	1.20

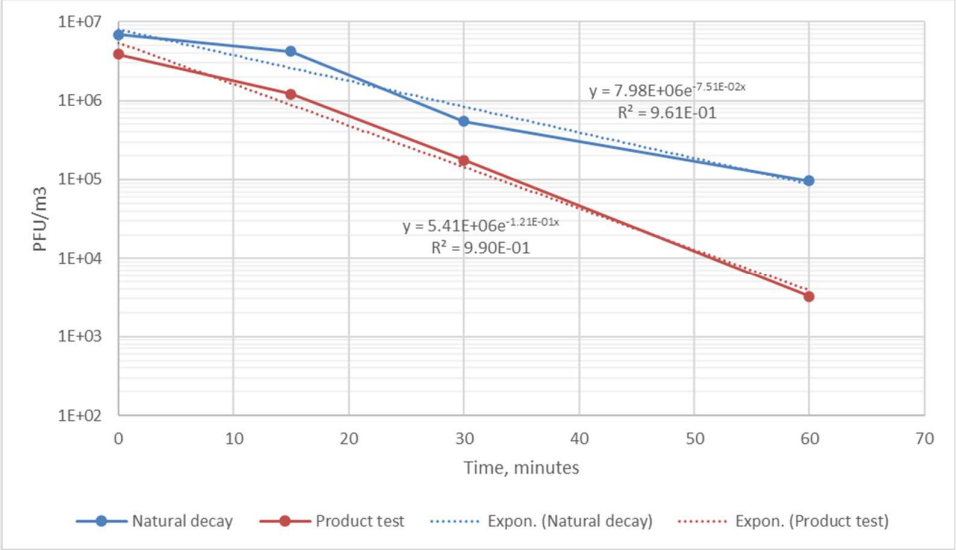

Figure 3: Fit to decay of the concentration of active MS2

Discussion

The performed test is designed to allow for direct evaluation of the effect of the air purifier on the concentration of aerosolized and active MS2 bacteriophages. The significant and consistent difference between the Natural decay test and the Product test clearly shows a reduction of the concentration of active MS2 caused by the air purifier.

A single test was performed so the uncertainty cannot be calculated.
However, the differently timed sampling point allows for an evaluation of the variability. If the sampling point at 60 minutes is removed from the dataset for the Product test (which is closest to the detection limit and thus more uncertain), the product attribution yields a 0.73 log-reduction per hour.
Therefore, the products attribution to the inactivation of MS2 likely falls in the interval of 0.73-1.2 log-reduction per hour.

It is worth mentioning that the product attribution to the reduction is due to inactivation of MS2 whereas the natural decay is mainly due to fallout of the MS2-containing aerosol to surfaces in the chamber.

The exponential reduction model and virus UV-susceptibility

The reduction rate of the concentration of aerosolized and active MS2 is found to be 0.73-1.2 log-reductions per hour and the mean value of these points yield of 0.97 log-reductions per hour (in the 20 m^3 test chamber). According to Kowalski W. (Ultraviolet Germicidal irradiation Handbook, Springer 2009), the UV-susceptibility of different type of viruses span about an order of magnitude and MS2 is among the lowest of the tested. The theoretical reduction rates of the air purifier are calculated for increasing UV-susceptibilities in Table 3 and shown in Figure 4.

Time, minutes	15	30	45	60	75	90	105	120
MS2 susceptibility: 0.97 log/hour								
Reduction, %	42.6	67.1	81.1	89.2	93.8	96.4	98.0	98.8
Log-reduction	0.24	0.48	0.72	0.97	1.21	1.45	1.69	1.93
3 times more susceptibly than MS2: 2.9 log/hour								
Reduction, %	81.1	96.4	99.3	99.9	99.976	99.995	99.999	99.9998
Log-reduction	0.72	1.45	2.17	2.90	3.62	4.34	5.07	5.79
5 times more susceptibly than MS2: 4.8 log/hour								
Reduction, %	93.8	99.6	99.976	99.999	99.9999	100	100	100
Log-reduction	1.21	2.41	3.62	4.83	6.03	7.24	8.44	9.65

Table 3: Reduction rates over time and for different UV-susceptibilities.

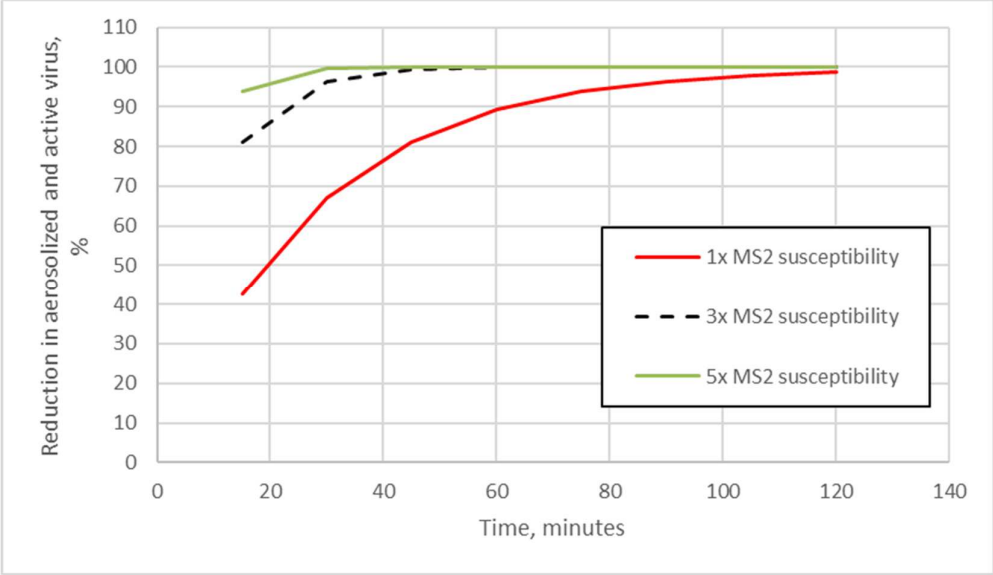

Figure 4: Reduction rate over time and for different UV-susceptibilities.

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5th of October 2020

Declaration of test and assessment

Danish Technological Institute has performed tests of the efficiency for inactivation virus of the Jimco MAC500 air purifier.

The test was conducted with the unit installed in a 20 m^3 sealed room. The efficiency of the air purifier was tested using MS2 bacteriophages (ATCC 15597-B1) on host *Escherichia coli* (ATCC 15597) as a virus surrogate. The rate of inactivation of the aerosolized MS2 was determined as the difference between the natural inactivation rate and the inactivation rate measured during the use of the Jimco MAC500 air purifier. These inactivation rates were determined by sampling of the air in the chamber over a 2-hour period. The significant and consistent difference between the Natural decay test and the Product test clearly shows a reduction of the concentration of airborne and active MS2 caused by the air purifier.

Based on the measured inactivation efficiency of the MAC500, the reductions in % and in log-reductions are calculated and are found in the table below:

Product attribution	**1 hour**	**2 hours**	**3 hours**
Reduction, %	89% ± 8%	99% ± 2.3%	99.9 ± 0.5%
Log-reduction (base 10)	0.97 ± 0.24	1.93 ± 0.47	2.9 ± 0.71

The full testing procedures and results are presented in report no. 933322.

According to Kowalski* and Walker† the UV-susceptibility for bacteriophage MS2 is lower than the UV-susceptibility for the enveloped virus, vaccinia virus. Hence, the indicated efficacy of the tested MAC500 UV-C device to degrade the bacteriophage MS2 will be at least similar to the efficacy against enveloped vaccinia virus. Efficacy against vaccinia virus allows for a claim for efficacy against all enveloped viruses (e.g. MERS-CoV, SARS-CoV-1 and SARS-CoV-2) according to DS/EN 14885:2018.

* Kowalski W. Ultraviolet Germicidal irradiation Handbook. Springer 2009

† Walker and Ko, ENVIRONMENTAL SCIENCE & TECHNOLOGY / VOL. 41, NO. 15, 2007

Best regards,

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5. Oktober 2020

Deklaration af test og bedømmelse

Teknologisk Institut har udført en effektivitetstest af luftrensen Jimco MAC500 for inaktivering af virus.

Testen blev udført med enheden installeret i et lukket 20 m^3 testkammer. Effektiviteten af luftrenseren blev testet med en virus-surrogat bestående af MS2 bakteriofager (ATCC 15597-B1) og en E.coli værtsorganisme (ATCC 15597).
Inaktiveringsraten af den aerosoliserede MS2 blev bestemt som forskellen mellem den naturlige inaktiveringsrate og inaktiveringsraten målt under drift af Jimco MAC500 luftrenseren. Disse inaktiveringsrater blev målt ved at udtrække luftprøver fra kammeret over en periode på to timer.
Den signifikante og konsistente forskel mellem det naturlige henfald og henfaldet målt med produktet i drift viser en tydelig reduktion i koncentrationen af aktive MS2 i luften forårsaget af luftrenseren.

Baseret på den målte inaktiveringseffektivitet af luftrenseren MAC500 så er reduktionerne beregnet og vist i tabellen nedenunder – i % og i log-reduktion:

Produktets tillæg	**1 time**	**2 timer**	**3 timer**
Reduktion, %	89% ± 8%	99% ± 2,3%	99,9 ± 0,5%
Log-reduktion (base 10)	0,97 ± 0,24	1,93 ± 0,47	2,9 ± 0,71

Den fulde beskrivelse af testen er dokumenteret i rapport nr. 933322.

According to Kowalski* and Walker† the UV-susceptibility for bacteriophage MS2 is lower than the UV-susceptibility for the enveloped virus, vaccinia virus. Hence, the indicated efficacy of the tested MAC500 UV-C device to degrade the bacteriophage MS2 will be at least similar to the efficacy against enveloped vaccinia virus. Efficacy against vaccinia virus allows for a claim for efficacy against all enveloped viruses (e.g. MERS-CoV, SARS-CoV-1 and SARS-CoV-2) according to DS/EN 14885:2018.

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5. Oktober 2020

Test- und Bewertungserklärung

Das Danish Technological Institute hat Tests durchgeführt, um die Effizienz des Jimco MAC500 Luftreinigers auf die Inaktivierung von Vira zu überprüfen.

Der Luftreiniger war während des Tests in einem 20 m3 großen versiegelten Raum installiert. Die Effizienz des Luftreinigers wurde unter Verwendung von MS2-Bakteriophagen (ATCC 15597-B1) auf Wirt-Escherichia coli (ATCC 15597) als Virussurrogat getestet. Die Inaktivierungsrate des MS2 Aerosols wurde als Differenz zwischen der natürlichen Inaktivierungsrate und der Inaktivierungsrate bestimmt, die während der Verwendung des Luftreinigers Jimco MAC500 gemessen wurde.
Diese Inaktivierungsraten wurden durch Probenahmen der Luft in der Kammer über einen Zeitraum von 2 Stunden bestimmt. Der signifikante und konsistente Unterschied zwischen dem natürlichen Inaktivierungstest ohne Luftreiniger und dem Test mit Luftreiniger zeigt deutlich eine Verringerung der Konzentration von luftgetragenem und aktivem MS2 bei Verwendung des Luftreinigers.

Basierend auf den gemessenen Werten für die Inaktivierungseffizienz des MAC500 wurde die Reduktion in % und log berechnet und in der folgenden Tabelle aufgelistet:

Produktzuordnung	**1 hour**	**2 hours**	**3 hours**
Reduktion, %	89% ± 8%	99% ± 2,3%	99,9 ± 0,5%
Log-Reduktion (Basis 10)	0,97 ± 0.24	1,93 ± 0,47	2,9 ± 0,71

Die vollständigen Testprozeduren sowie alle Ergebnisse sind im Bericht Nr. 933322 zu finden.

According to Kowalski* and Walker† the UV-susceptibility for bacteriophage MS2 is lower than the UV-susceptibility for the enveloped virus, vaccinia virus. Hence, the indicated efficacy of the tested MAC500 UV-C device to degrade the bacteriophage MS2 will be at least similar to the efficacy against enveloped vaccinia virus. Efficacy against vaccinia virus allows for a claim for efficacy against all enveloped viruses (e.g. MERS-CoV, SARS-CoV-1 and SARS-CoV-2) according to DS/EN 14885:2018.

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5/10/2020

Declaración y evaluación de test

El Instituto Tecnológico de Dinamarca ha realizado un test de eficiencia en la inactivación de virus del purificador de aire Jimco MAC500.

El test fue realizado con una unidad instalada en una cámara sellada de 20 m3. La eficiencia de inactivación del purificador de aire se realizó con un substituto de virus, compuesto por el bacteriófago MS2 (ATCC 15597-B1) y una bacteria huésped, E.coli (ATCC 15597).

La tasa de inactivación del MS2 en forma de aerosol se determinó como la diferencia entre la tasa de inactivación natural y la tasa de inactivación medida durante la operación del purificador de aire Jimco MAC500. Estas tasas de inactivación fueron medidas durante la extracción de las muestras de aire en un periodo de 2 horas.

La diferencia significante y consistente obtenida entre la disminución natural del MS2 y la medida en el producto bajo operación, muestra una clara reducción en la concentración de MS2 en el aire, producto del efecto del purificador de aire.

Con base en la eficiencia de inactivación medida en el purificador de aire MAC500, las reducciones se calculan y se muestran en la siguiente tabla, en % y en reducción logarítmica:

Atribuciones del producto	**1 hora**	**2 horas**	**3 horas**
Reducción %	89% ± 8%	99% ± 2,3%	99,9% ± 0,5%
Reducción logarítmica (base 10)	0,97 ± 0,24	1,93 ± 0,47	2,9 ± 0,71

La descripción completa del test está documentada en el informe Nº 933322.

According to Kowalski* and Walker† the UV-susceptibility for bacteriophage MS2 is lower than the UV-susceptibility for the enveloped virus, vaccinia virus. Hence, the indicated efficacy of the tested MAC500 UV-C device to degrade the bacteriophage MS2 will be at least similar to the efficacy against enveloped vaccinia virus. Efficacy against vaccinia virus allows for a claim for efficacy against all enveloped viruses (e.g. MERS-CoV, SARS-CoV-1 and SARS-CoV-2) according to DS/EN 14885:2018.

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Saludos cordiales,

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