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TITLE:	Efficacy testing of NV1050 device against <i>Staphylococcus epidermidis</i> bacteria
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DATE:	June 27, 2018
KEYWORDS:	<i>Staphylococcus epidermidis</i> , colony forming units (CFU), clean air delivery rate (CADR)

Background: The current study characterises the decontamination efficacy of the NV 1050 device against aerosolized *Staphylococcus epidermidis* bacterial cells. The NV1050 is designed to eradicate airborne pathogens, including bacteria, viruses, fungi and spores. The study was carried out in a 30m³ environmental chamber and includes two test runs and two control runs.

Methods: Bacterial cells of *Staphylococcus epidermidis* were aerosolized into a sealed environmental test chamber using a jet nebulizer. Bacterial cells were recovered from the air using an SKC Biosampler. The recovered bacterial cell suspension was diluted and plated in duplicate for each test and control run to determine the concentration of microbial cells in the air. Samples were taken every 15 minutes. The test data was compared to the control data to determine the reduction in microbial cell concentration.

Results: The NV1050 achieved a microbial cell reduction of 99.9% within 15 minutes of operation following the nebulization of microbial cells in the test chamber; the device was operated at maximum airflow speed. The equivalent reduction in log scale is log-3 within 15 minutes. The equivalent clean air delivery rate is also estimated from the data to be 919 m³/hr.

1 PROJECT SCOPE AND OBJECTIVES

The NOVAERUS NV1050 air disinfection device is designed to quickly reduce the concentration of any viable airborne pathogen within an indoor environment. The NV1050 removes and inactivates airborne pathogens with the use of the in-built plasma technology coupled with a HEPA and carbon filters. The aim of the study is to test the efficacy of the NV1050 within a controlled test chamber against the bacterial strain: *Staphylococcus epidermidis* (ATCC 12228). The NV1050 device was operated at maximum airflow speed in this study.

2 TEST PROCEDURE

The test environment is a 30 m³ test chamber, located in the NOVAERUS microbiology laboratory at NOVAERUS R&D department in Dublin, Ireland. During the testing, the NV1050 device was placed inside the test chamber and located in the centre of the same with the air inlet facing towards the

door of the test chamber. The test procedure followed is documented in 'SOP93.00 Bacterial Test Procedure – Large Chamber' [1]. The NV1050 device was tested at maximum airflow, speed setting 5. The test chamber is controlled for temperature and humidity at 25°C and 50% relative humidity.

A 24-Jet Collison nebuliser was used to generate the bioaerosol and disperse the bacterial culture into the test chamber. The challenge bacteria were delivered into the chamber for 20 minutes. Immediately after nebulising the time 0 sample (T0) sample was collected with an SKC bio-sampler for 5 minutes at 12.5 L/m. The NV1050 was turned 'ON' immediately after sample T0 via power switches outside the test chamber. The NV1050 treated the air within the chamber for a total exposure time of 1.5 hours at speed 5. Another 6 air samples were taken from the chamber at 15-minute intervals until the end of the 1.5-hour exposure time. The samples were serially diluted and plated in duplicate to determine viable organism bioaerosol concentration reduction during the exposure.

Control testing was performed to provide baseline comparative data to assess the actual reduction from NV1050 challenge testing. Control testing was performed with the absence of the NV1050 inside the environmental chamber.

Two controls and two test runs were completed over 4 days of work.

3 TEST SCHEDULE

The schedule of testing is summarized in Table 1.

Table 1: Schedule of microbial challenge tests of NV1050 device in 30 m³ environmental test chamber.

Test No.	Date	Run	NV Device	Species	Challenge conc.	Speed Setting	Total test time (min)	Sampling
1	01/06/18	Control	No device present	<i>Staphylococcus epidermidis</i> . (ATCC 12228)	10 ⁵	Speed 5	90	Bio-sampler
2	06/06/18	Challenge	NV1050	<i>Staphylococcus epidermidis</i> . (ATCC 12228)	10 ⁵	Speed 5	90	Bio-sampler
3	07/06/18	Control	No device present	<i>Staphylococcus epidermidis</i> . (ATCC 12228)	10 ⁵	Speed 5	90	Bio-sampler
4	08/06/18	Challenge	NV1050	<i>Staphylococcus epidermidis</i> . (ATCC 12228)	10 ⁵	Speed 5	90	Bio-sampler

4 RESULTS

The results of control and test runs are summarized in Table 2. The concentration of surviving *Staphylococcus epidermidis* bacterial cells is given in millions of CFU per cubic meter (10⁶ x CFU/m³).

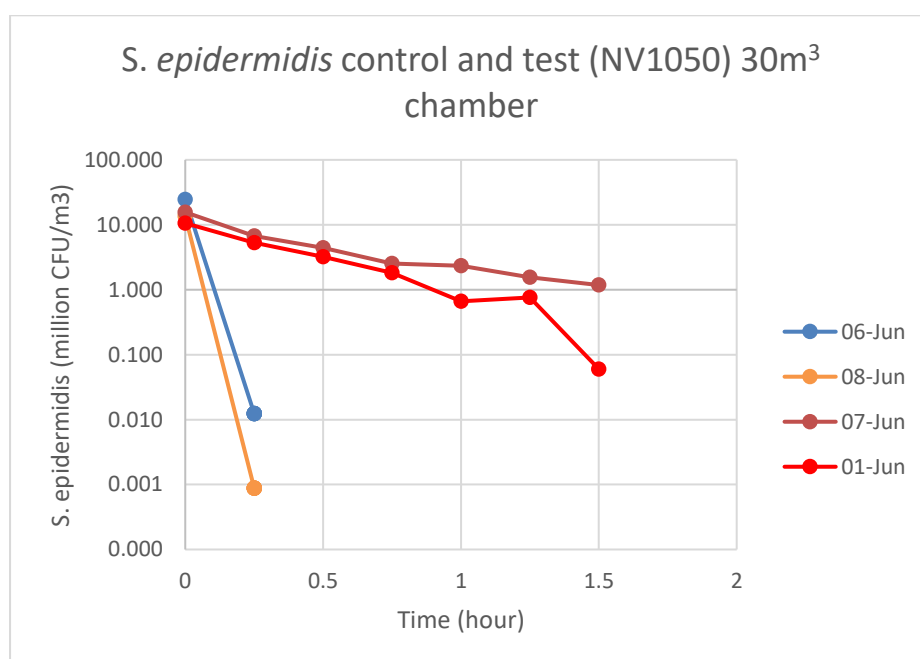
This is the estimated concentration of bacterial cells per unit of volume in the air. Note that the concentration of bacterial cells for test runs at time greater and equal to 30 minutes is null; i.e. no colony growth on plates observed.

The data of Table 2 is plotted in Figure 1 where the vertical axis is in a logarithmic scale.

The average bacterial net reduction is **99.94%** at 15 minutes. The bacterial log reduction is **3.2 log** at 15 minutes.

Table 2: Control and test run results. The bacterial concentration is in millions of CFU per cubic meter ($10^6 \times \text{CFU/m}^3$).

	Control		NV1050	
	Test No.			
	1	3	2	4
	Date			
	01-Jun	07-Jun	06-Jun	08-Jun
Time (hour)	S. epidermidis (million CFU/m ³)			
0	10.580	15.600	24.400	13.600
0.25	5.320	6.740	0.012	0.001
0.5	3.200	4.400	0.000	0.000
0.75	1.820	2.520	0.000	0.000
1	0.660	2.340	0.000	0.000
1.25	0.760	1.560	0.000	0.000
1.5	0.060	1.180	0.000	0.000

Figure 1: Survival curves for *S. epidermidis*, control and test results in 30 m³ test chamber.

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5 CONCLUSION

The performance of the NV1050 is proven very effective in reducing the bioburden within the test chamber within a 30-minute exposure time at the highest speed setting.

6 REFERENCES

- [1] SOP093.00 Bacterial Test Procedure – Large Chamber, Revision 1, 25 May 2018

7 APPENDIX

Test and control bacterial data collected. Conversion from CFU count to airborne concentration.

NV1050										NV1050										Control										Control									
06/06/2018										08/06/2018										07/06/2018										01/06/2018									
Bio-sampler										Bio-sampler										Bio-sampler										Bio-sampler									
Dilution (per mL)	CFU	CFU/mL (dilution)	million CFU/m ³ (air)	Dilution (per mL)	CFU	CFU/mL (dilution)	million CFU/m ³ (air)	Dilution (per mL)	TNTC	#VALUE!	#VALUE!	million CFU/m ³ (air)	Dilution (per mL)	CFU	CFU/mL (dilution)	#VALUE!	#VALUE!	million CFU/m ³ (air)	Dilution (per mL)	CFU	CFU/mL (dilution)	million CFU/m ³ (air)																	
1.00E-03	TNTC	#VALUE!	#VALUE!	1.00E-03	TNTC	#VALUE!	#VALUE!	1.00E-03	TNTC	#VALUE!	#VALUE!		1.00E-03	TNTC	#VALUE!	#VALUE!				1.00E-03	136	1.36E+05	10880																
1.00E-04	TNTC	#VALUE!	#VALUE!	1.00E-04	TNTC	#VALUE!	#VALUE!	1.00E-04	TNTC	#VALUE!	#VALUE!		1.00E-04	TNTC	#VALUE!	#VALUE!				1.00E-03	143	1.43E+05	11440																
1.00E-04	29	2.90E+05	23200	1.00E-04	16	1.60E+05	12800	1.00E-04	16	1.60E+05	12800	12.8	1.00E-04	17	1.70E+05	13600			13.6	1.00E-04	11	1.10E+05	8800																
1.00E-04	32	3.20E+05	25600	1.00E-04	18	1.80E+05	14400	1.00E-04	18	1.80E+05	14400	14.4	1.00E-04	22	2.20E+05	17600			17.6	1.00E-04	14	1.40E+05	11200																
1.00E+00	TNTC	#VALUE!	#VALUE!	1.00E+00	14	1.40E+01	1.12	1.00E+00	14	1.40E+01	1.12	0.00112	1.00E-03	82	8.20E+04	6560			6.56	1.00E-03	53	5.30E+04	4240																
1.00E+00	TNTC	#VALUE!	#VALUE!	1.00E+00	10	1.00E+01	0.8	1.00E+00	10	1.00E+01	0.8	0.0008	1.00E-03	85	8.50E+04	6800			6.8	1.00E-03	63	6.30E+04	5040																
1.00E-01	16	1.60E+02	12.8	1.00E-01	1	1.00E+01	0.8	1.00E-01	1	1.00E+01	0.8	0.0008	1.00E-04	8	8.00E+04	6400			6.4	1.00E-04	7	7.00E+04	5600																
1.00E-01	15	1.50E+02	12	1.00E-01	1	1.00E+01	0.8	1.00E-01	1	1.00E+01	0.8	0.0008	1.00E-04	9	9.00E+04	7200			7.2	1.00E-04	8	8.00E+04	6400																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	49	4.90E+04	3920			3.92	1.00E-03	47	4.70E+04	3760																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	51	5.10E+04	4080			4.08	1.00E-03	43	4.30E+04	3440																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	5	5.00E+04	4000			4	1.00E-04	4	4.00E+04	3200																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	7	7.00E+04	5600			5.6	1.00E-04	3	3.00E+04	2400																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	35	3.50E+04	2800			2.8	1.00E-03	23	2.30E+04	1840																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	31	3.10E+04	2480			2.48	1.00E-03	28	2.80E+04	2240																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	2	2.00E+04	1600			1.6	1.00E-04	3	3.00E+04	2400																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	4	4.00E+04	3200			3.2	1.00E-04	1	1.00E+04	800																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	26	2.60E+04	2080			2.08	1.00E-03	11	1.10E+04	880																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	31	3.10E+04	2480			2.48	1.00E-03	12	1.20E+04	960																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	3	3.00E+04	2400			2.4	1.00E-04	0	0.00E+00	0																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	3	3.00E+04	2400			2.4	1.00E-04	1	1.00E+04	800																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	24	2.40E+04	1920			1.92	1.00E-03	8	8.00E+03	640																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	24	2.40E+04	1920			1.92	1.00E-03	10	1.00E+04	800																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	2	2.00E+04	1600			1.6	1.00E-04	1	1.00E+04	800																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	2	2.00E+04	1600			1.6	1.00E-04	1	1.00E+04	800																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	18	1.80E+04	1440			1.44	1.00E-03	2	2.00E+03	160																
1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	1.00E+00	0	0.00E+00	0	0	1.00E-03	21	2.10E+04	1680			1.68	1.00E-03	1	1.00E+03	80																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	1	1.00E+04	800			0.8	1.00E-04	0	0.00E+00	0																
1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	1.00E-01	0	0.00E+00	0	0	1.00E-04	1	1.00E+04	800			0.8	1.00E-04	0	0.00E+00	0																

Example of calculation of airborne bacteria concentration.							
Bio-sampler							
Dilution (per mL)	CFU	CFU/mL (dilution)	CFU/L (air)	CFU/m ³ (air)			
1.00E-04	78	780000	62400	62400000			
1.00E-04	89	890000	71200	71200000			
1.00E-05	5	500000	40000	40000000			
1.00E-05	6	600000	48000	48000000			
Description of the contents of each cell in the example above							
Dilution of liquid volume in the bio-sampler.	Colony forming units count on plate for each dilution plated.	The concentration of CFU per mL of solution in the bio-sampler. 5mL in sampler, run for 5 min at 12.5 L/min. Therefore the sampler collects 12.5 L air / mL of solution.	The converted CFU concentration per litre of air.	The converted CFU concentration per cubic meter.			

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Data analysis: averaging and equivalent clean air delivery rate (CADR) calculation.

CFU / m3 in air				Normalized survival curves				Average Test and Control runs				Reduction % and log				LN of normalized data										
NV1050				NV1050				NV1050				NV1050				NV1050										
Control				Control				Control				Control				Control										
Time (hour)	06-Jun	08-Jun	07-Jun	01-Jun	Time (hour)	06-Jun	08-Jun	07-Jun	01-Jun	Time (hour)	0	0.25	0.5	0.75	1	1.25	1.5	Time (hour)	0	0.25	0.5	0.75	1	1.25	1.5	
0	24.400	13.600	15.600	10.580	0	1.000	1.000	1.000	1.000	0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0	0.000%	0	0	0	0	0	0	0
0.25	0.012	0.001	6.740	5.320	0.25	0.001	0.000	0.432	0.503	0.25	0.000	0.467	0.292	0.167	0.106	0.086	0.041	0.25	99.939%	3.213	0.25	0.25	0.25	0.25	0.25	
0.5	0.000	0.000	4.400	3.200	0.5	0.000	0.000	0.282	0.302	0.5	0.000	0.292	0.167	0.106	0.086	0.041	0.041	0.5	100.000%	#NUM!	0.5	0.5	0.5	0.5	0.5	
0.75	0.000	0.000	2.520	1.820	0.75	0.000	0.000	0.162	0.172	0.75	0.000	0.167	0.106	0.086	0.041	0.041	0.041	0.75	100.000%	#NUM!	0.75	0.75	0.75	0.75	0.75	
1	0.000	0.000	2.340	0.660	1	0.000	0.000	0.150	0.062	1	0.000	0.106	0.086	0.041	0.041	0.041	0.041	1	100.000%	#NUM!	1	1	1	1	1	
1.25	0.000	0.000	1.560	0.760	1.25	0.000	0.000	0.100	0.072	1.25	0.000	0.086	0.041	0.041	0.041	0.041	0.041	1.25	100.000%	#NUM!	1.25	1.25	1.25	1.25	1.25	
1.5	0.000	0.000	1.180	0.060	1.5	0.000	0.000	0.076	0.006	1.5	0.000	0.041	0.041	0.041	0.041	0.041	0.041	1.5	100.000%	#NUM!	1.5	1.5	1.5	1.5	1.5	
million CFU/m3 air																				slope						
NV1050 tested with M5 pre-filter.																				R-square						
																				diff. slope						
																				Volume						
																				CADR						
																				919 m3/hr						
																				30 m3						
																				1						
																				-32.63						
																				-2.00						
																				0.985						
																				30.63 (hr-1)						
																				-2.454						
																				-3.203						
																				-2.243						
																				-1.791						
																				-1.230						
																				-0.760						
																				0.000						
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