Validation of the Novaerus NV1050 Air Cleaner to the Liverpool Biovalidation Protocol

Background: This in vitro study demonstrated the efficacy of the Defend NV1050 device at removing aerosolized *Micrococcus luteus* bacteria. The NV1050 device is designed to reduce airborne bacteria, viruses, and fungal spores in order to decrease infection rates from airborne pathogens.

Methods: *Micrococcus luteus* was aerosolized into a 58.8m^3 room containing the NV1050 for evaluation. The NV1050 was evaluated at fan speed 5 and air samples were taken every 5 or 10 minutes depending on the test in order to quantify the reduction capabilities of the device at maximum speed. Control trial data was subtracted from the NV1050 trial data to yield net LOG reduction for bioaerosol reductions. An external company was used to count samples to ensure the results were blinded.

Results Summary: The NV1050 average bacterial reduction of 99.2% (2.08 log) in 60 minutes in a 58.8m^3 room.

INTRODUCTION

This study was conducted by the Academic Health Science Networks (AHSN) as part of the National Health Services Environmental decontamination framework evaluation in the UK.

The effectiveness of the NV1050 device was evaluated against *Micrococcus luteus* bacteria over a period of one hour. Testing mimicked real world settings to determine the disinfection capabilities against aerosolised bacteria in a room setting.

Figure 1: Novaerus NV1050 device

Date: 1st September 2022

BIOAEROSOL TESTING CHAMBER

A sealed room was used for bioaerosol testing representing a real-world evaluation setting. The temperature of the room was equilibrated to a 23.5°C ± 0.5°, the humidity was 50% ± 2% and the interior air was mixed at high-speed using four oscillating fans of at least 30cm diameter, mounted in each corner of the room at a height of 1m from the floor.

The walls and ceiling were constructed from material that was easily washed down and the carpet present was disinfected thoroughly with a bleach-based disinfectant.

Nebulisation was conducted directly in front of one of the fans.

Air sampling took place one third along the longest dimension of the room mid-way along the shortest dimension part-way between the floor and ceiling.

Continuous temperature and humidity monitoring was conducted at multiple locations within the room/chamber and additional heating, cooling, humidification or dehumidification performed to maintain the environmental conditions. The NV1050 device was floor-mounted, one third along the longest dimension of the room opposing the air sampler and mid-way along the shortest dimension. It was ensured that the output of the NV1050 was not directed towards the air sampler input orifice.

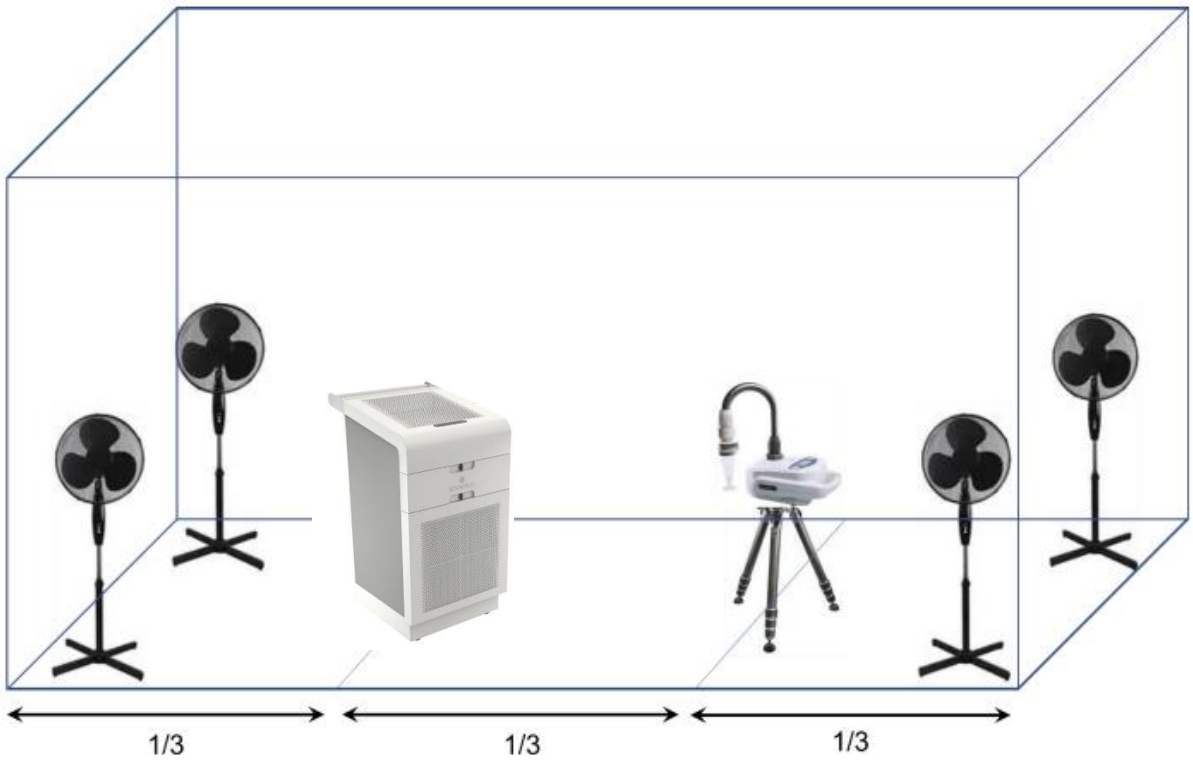


Figure 2: Environmental chamber arrangement

Date: 1st September 2022

CHAMBER SEEDING AND AIR SAMPLING

Prior to seeding of the chamber, a bacterial suspension of *Micrococcus luteus* was prepared and maintained between 2-7°C to ensure maximum viability prior to experimentation. A volume of bacterial suspension for a final chamber concentration of up to $2x10^8/m^3$ was added to the nebuliser and the suspension fully aerosolized, subsequently allowing the room to equilibrate for approximately 10 minutes.

Baseline characterisation of the room was conducted by sampling the air at least every 5 minutes for one hour prior to testing of the air purifier, ensuring that the air temperature and humidity were maintained at the equilibrium level. An appropriate volume of air was sampled (approximately 200L) such that a sufficient volume was sampled to allow several log reductions in bacterial numbers could be measured while removing an insignificant proportion of the total.

A Coriolis biological air sampler was used to collect the bio-aerosol samples. Air sampling was conducted into 10ml volume of MRD - a fluid able to maintain the viability of the bacteria and prevent additional cell replication.

Air was sampled from the room after switching on the air purifier either every 10 minutes over a period of an hour, or every 5 minutes over half an hour. The sampled bacteria were maintained at 2-7°C until plated to ensure viability was retained.

The room was comprehensively disinfected after completion of sampling.

ENUMERATION OF BACTERIA AND EVALUATION OF AIR PURIFIERS

Each MRD sample was plated out in duplicate TSA plates using a spiral plater, allowing a $2x\ 10^4$ dynamic range of cell number enumeration. Plates were sent on to an external company to be enumerated to ensure the results were blind to the persons carrying out the testing.

The base 10-logarithm of full room equivalent values of the bacteria were plotted against time. The baseline characteristics of bacterial loss were first subtracted.

The performance of the air purifier was calculated from the derived decay curve in terms of the total $\log_{10}$ reduction in the room over an hour and the number of seconds required for the air purifier to reduce the bacterial numbers in $1m^3$ by $1 \times \log_{10}$.

BIOAEROSOL CONTROL TESTING

Results have been normalised to take into account a lower performance of the standard control for bacterial destruction for particular measurements.

Due to methodical reasons, accurate measurements of bacterial numbers at high log reductions was not possible. For this reason, measurements were performed at 5 minute intervals and for a shorter duration for some measurements to preserve the quality of the data. Calculation of the bacterial CFU reduction curve was conducted on the accurate measurements only.

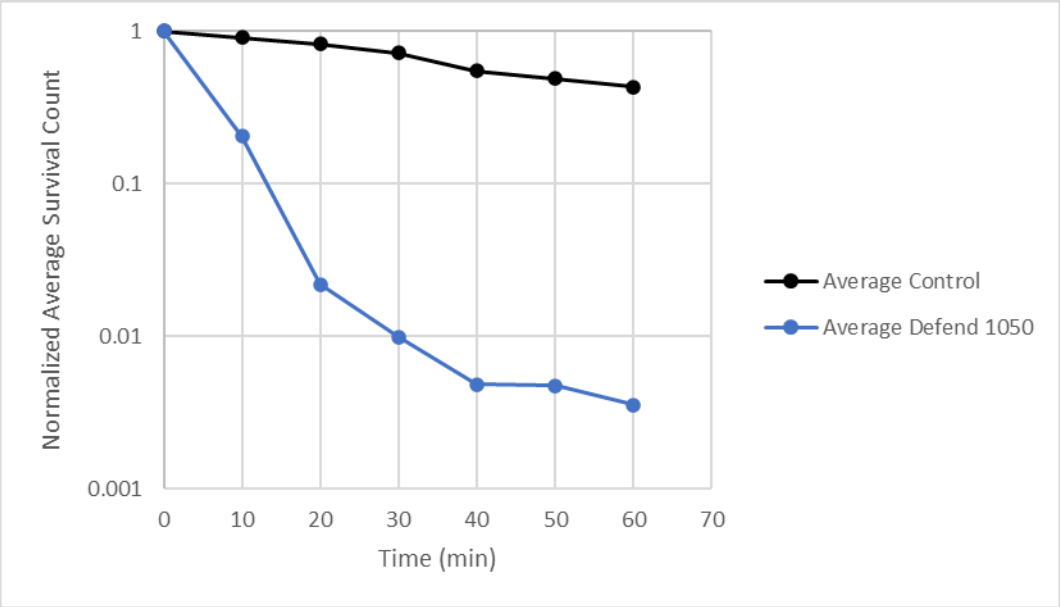
Mean temperature and humidity have been calculated from the start and end reading of each test and control.

Date: 1st September 2022

A value of 0.414 log_{10} reductions has been deducted from each result, representing the mean decay in bacterial numbers as measured in the same room without any air purification but with air mixing (SD =0.14, n =8)

NV1050 TEST RESULTS

Time (mins)	Average Reduction (%)	Average Log reduction
0	0.0%	0.00
10	77.3%	0.64
20	97.3%	1.57
30	98.6%	1.86
40	99.1%	2.06
50	99.0%	2.01
60	99.2%	2.08



Date: 1st September 2022

Validation of the Novaerus NV1050 Air Scrubber to the Liverpool Biovalidation Protocol

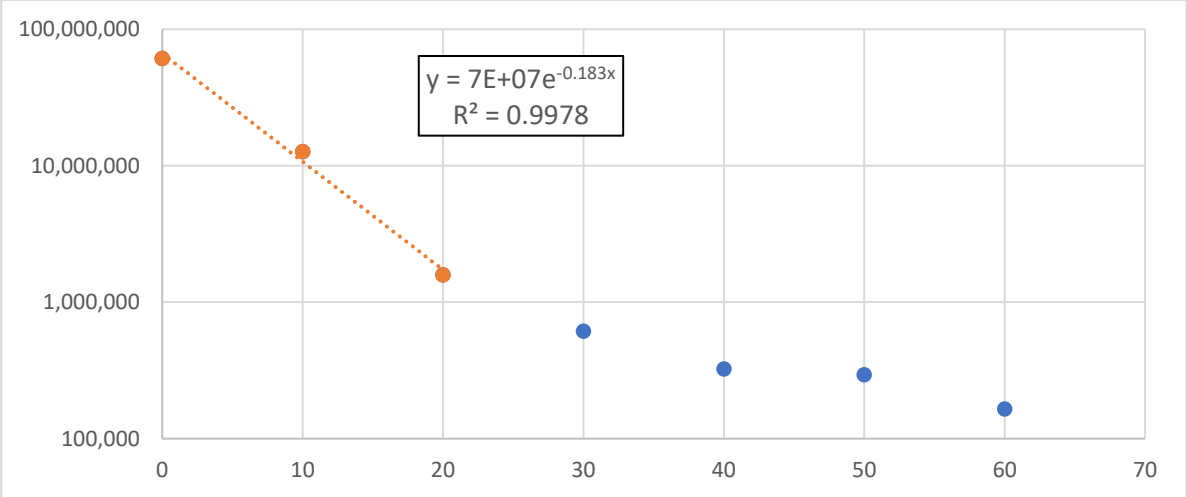
Novaerus NV1050

Ref	AS0003	
Room	Chamber 1	
Room size	58.8	m^3
Mean Temp	22.9	°C
Mean RH	50.3	%
Fan Setting	5	

27/04/2022

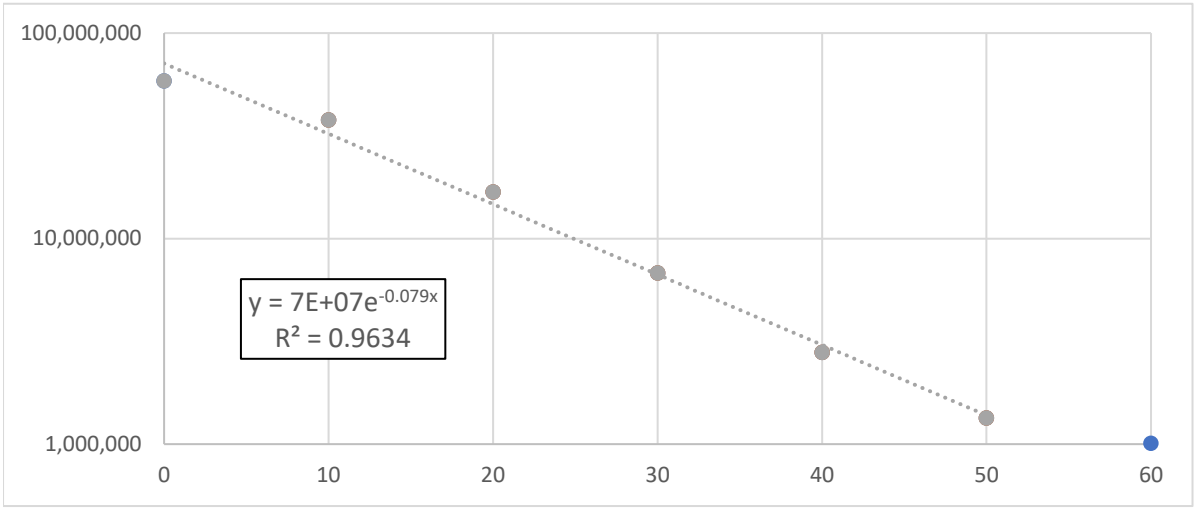
n = 1

Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
1.94E+05	2.22E+05	0	61,152,000	Exp	-0.183
3.94E+04	4.67E+04	10	12,656,700	Intcpt	7.00E+07
5.47E+03	5.33E+03	20	1,587,600	Calc 60'	1.19E+03
1.46E+03	2.72E+03	30	614,460	Log Redcn	4.77
1.16E+03	1.04E+03	40	323,400	- room	0.41
1.08E+03	9.20E+02	50	294,000	NET	4.35
5.40E+02	5.80E+02	60	164,640		



Control device

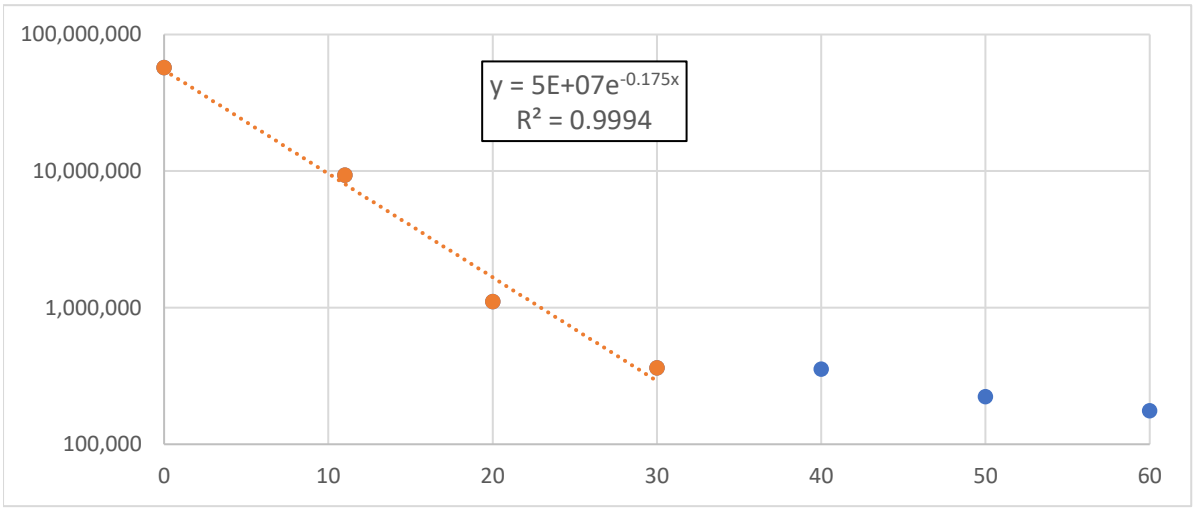
Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
1.78E+05	2.20E+05	0	58,506,000	Exp	-0.079
1.44E+05	1.13E+05	10	37,779,000	Intcpt	7.00E+07
4.96E+04	6.50E+04	20	16,846,200	Calc 60'	6.12E+05
2.08E+04	2.55E+04	30	6,806,100	Log Redcn	2.06
8.10E+03	1.09E+04	40	2,793,000	- room	0.41
4.32E+03	4.80E+03	50	1,340,640	NET	1.64
2.88E+03	4.00E+03	60	1,011,360		



03/05/2022

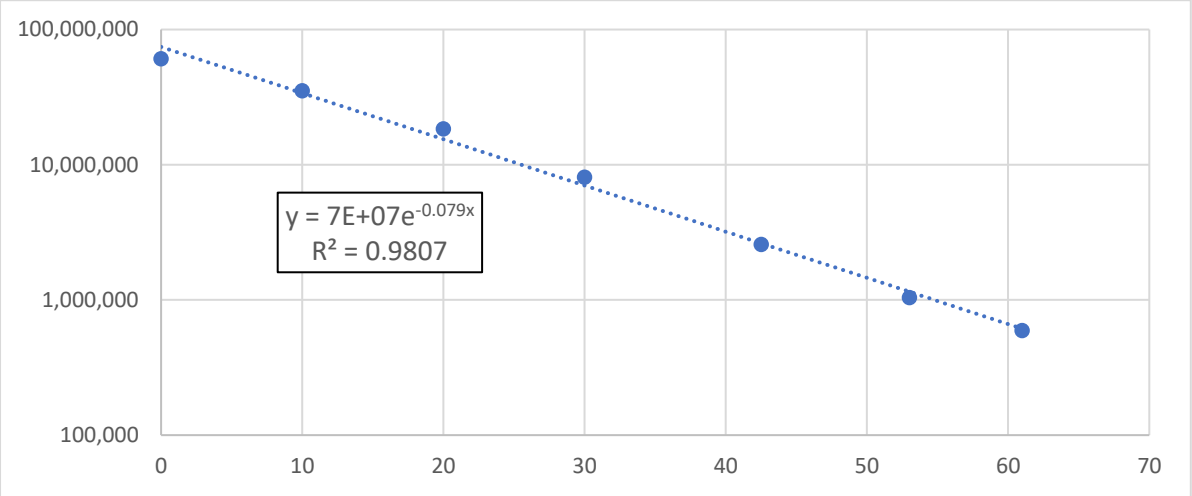
n = 2

Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
2.09E+05	1.80E+05	0	57,183,000	Exp	-0.175
2.99E+04	3.36E+04	11	9,334,500	Intcpt	5.00E+07
4.93E+03	2.60E+03	20	1,106,910	Calc 60'	1.38E+03
1.28E+03	1.18E+03	30	361,620	Log Redcn	4.56
1.00E+03	1.42E+03	40	355,740	- room	0.41
6.80E+02	8.40E+02	50	223,440	NET	4.15
5.00E+02	7.00E+02	60	176,400		



Control device

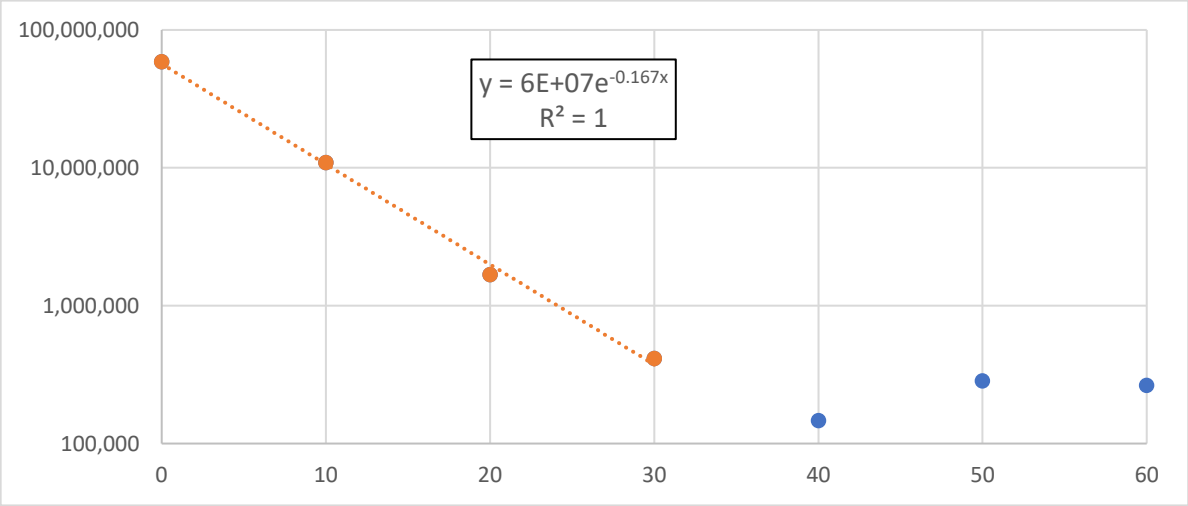
Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
2.09E+05	2.04E+05	0	60,711,000	Exp	-0.079
1.07E+05	1.33E+05	10	35,280,000	Intcpt	7.00E+07
7.41E+04	5.11E+04	20	18,404,400	Calc 60'	6.12E+05
2.85E+04	2.65E+04	30	8,085,000	Log Redcn	2.06
7.88E+03	9.63E+03	42.5	2,573,970	- room	0.41
3.32E+03	3.76E+03	53	1,040,760	NET	1.64
2.06E+03	1.98E+03	61	593,880		



04/05/2022

n = 3

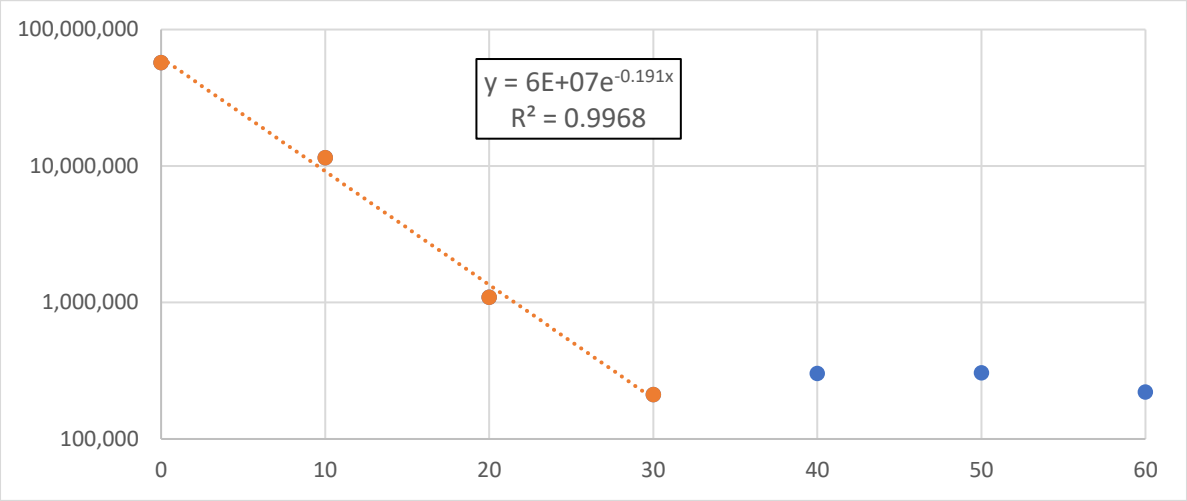
Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
2.02E+05	1.98E+05	0	58,800,000	Exp	-0.167
3.50E+04	3.94E+04	10	10,936,800	Intcpt	6.00E+07
6.78E+03	4.64E+03	20	1,678,740	Calc 60'	2.67E+03
1.22E+03	1.60E+03	30	414,540	Log Redcn	4.35
4.40E+02	5.60E+02	40	147,000	- room	0.41
1.06E+03	8.80E+02	50	285,180	NET	3.94
7.80E+02	1.02E+03	60	264,600		



n = 4

Plate Count 1	Plate Count 2	Time (mins)	Room Count
1.80E+05	2.09E+05	0	57,183,000
3.94E+04	3.87E+04	10	11,480,700
4.00E+03	3.44E+03	20	1,093,680
8.20E+02	6.20E+02	30	211,680
1.06E+03	1.00E+03	40	302,820
1.30E+03	7.80E+02	50	305,760
7.00E+02	8.00E+02	60	220,500

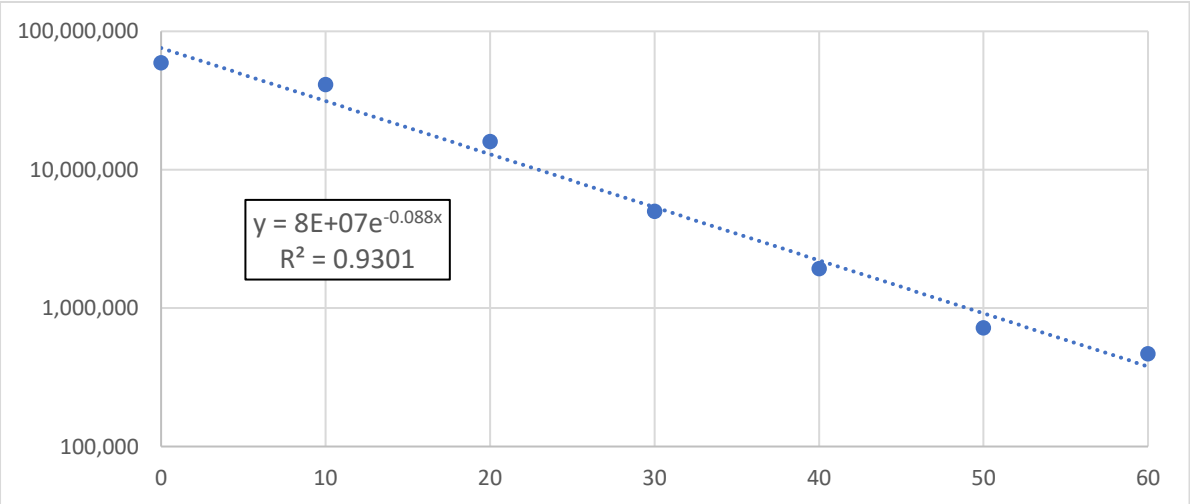
	1 hour trend
Exp	-0.191
Intcpt	6.00E+07
Calc 60'	6.33E+02
Log Redcn	4.98
- room	0.41
NET	4.56



Control Device

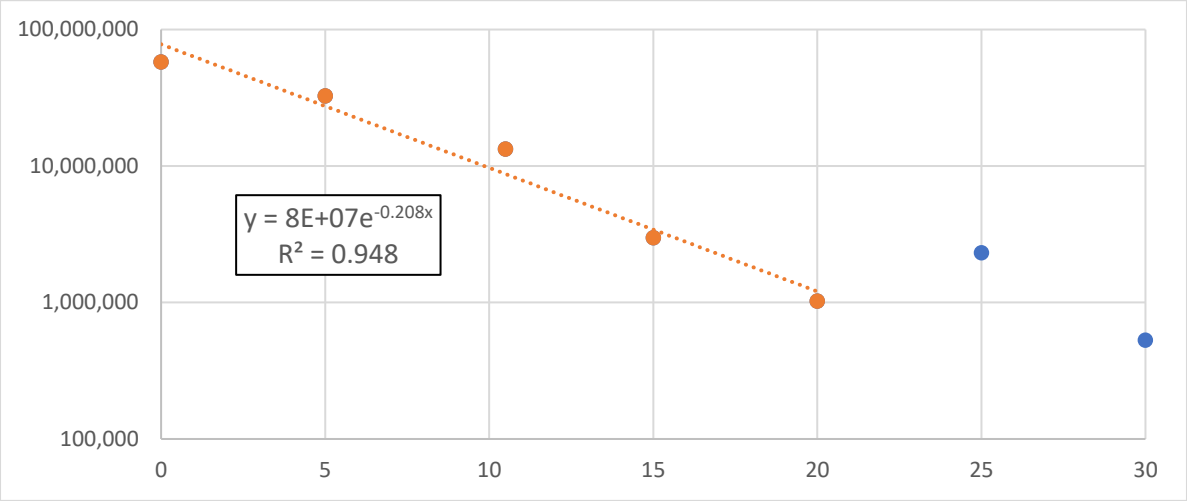
Plate Count 1	Plate Count 2	Time (mins)	Room Count
1.98E+05	2.04E+05	0	59,094,000
1.50E+05	1.30E+05	10	41,160,000
5.18E+04	5.69E+04	20	15,978,900
1.55E+04	1.86E+04	30	5,012,700
7.20E+03	5.92E+03	40	1,928,640
2.56E+03	2.34E+03	50	720,300
1.64E+03	1.54E+03	60	467,460

	1 hour trend
Exp	-0.088
Intcpt	8.00E+07
Calc 60'	4.07E+05
Log Redcn	2.29
- room	0.41
NET	1.88



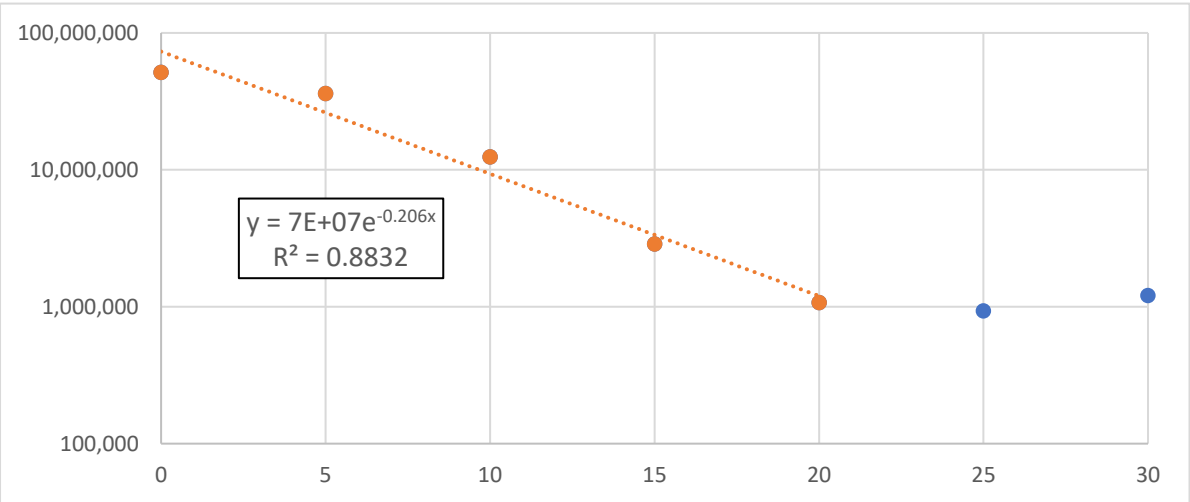
n = 5

Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
1.72E+05	2.22E+05	0	57,918,000	Exp	-0.208
1.37E+05	1.33E+05	5	32,685,882	Intcpt	8.00E+07
4.53E+04	4.53E+04	10.5	13,318,200	Calc 60'	3.04E+02
9.63E+03	1.07E+04	15	2,988,510	Log Redcn	5.42
3.92E+03	3.04E+03	20	1,023,120	- room	0.41
7.60E+03	8.10E+03	25	2,307,900	NET	5.01
2.08E+03	1.52E+03	30	529,200		



n = 6

Plate Count 1	Plate Count 2	Time (mins)	Room Count		1 hour trend
1.70E+05	1.81E+05	0	51,597,000	Exp	-0.206
1.33E+05	1.13E+05	5	36,162,000	Intcpt	8.00E+07
3.94E+04	4.53E+04	10	12,450,900	Calc 60'	3.43E+02
1.09E+04	8.67E+03	15	2,876,790	Log Redcn	5.37
3.44E+03	3.86E+03	20	1,073,100	- room	0.41
2.90E+03	3.44E+03	25	931,980	NET	4.95
3.40E+03	4.80E+03	30	1,205,400		



Results summary (bacterial killing curve)

Log_{10} reduction over an hour in a 58.8 m^3 chamber

Unnormalised results

	NV1050	Control §
n=1	4.35	1.64
n=2	4.15	1.64
n=3	3.95	1.88
n=4	4.56	
n=5	5.01	
n=6	4.95	
Mean	**4.50**	**1.72**
SD	**0.43**	**0.14**
Performance	13.6	35.6

* Performance measured as duration in seconds to reduce bacterial count in $1m^3$ by 1 log_{10} reduction

§ Expected Control bacterial reduction based on previous results (n = 33): 1.89 log_{10} reductions

Normalised results

	NV1050	Control §
n=1	5.01	1.89
n=2	4.78	1.89
n=3	3.95	1.88
n=4	4.56	
n=5	5.01	
n=6	4.95	
Mean	**4.71**	**1.89**
SD	**0.41**	**0.01**
Performance	13.0	32.5

* Performance measured as duration in seconds to reduce bacterial count in $1m^3$ by 1 log_{10} reduction

§ NV1050 results normalised to historical control bacterial reduction values based on previous results (n = 33): 1.89 log_{10} reductions

Notes

1. The results have been normalised to take into account a lower performace of the standard control for bacterial desctruction for particular measurements. Both unnormalised and normalised have been included for comparison.
2. Due to methodological reasons, accurate measurement of bacterial numbers at high log reductions was not possible. For this reason, measurements were performed at 5 minute intervals and for a shorter duration for some measurements to preserve the quality of the data. Calculation of the bacterial CFU reduction curve was conducted on the accurate measurements only.
3. Mean temperature and humidity have been calculated from the start and end reading of each test machine and control (n = 18).
4. A value of 0.414 log_{10} reductions has been deducted from each result, representing the mean decay in bacterial numbers as measured in the same chamber without any air purification but with air mixing (SD = 0.14, n = 8).

For and on behalf of the Innovation Agency
26.05.2022, Dr Nicholas Rhodes PhD & Prof Anthony Fisher PhD MD

Nicholas P. Rhodes

Room 1 validation: natural decay characteristics

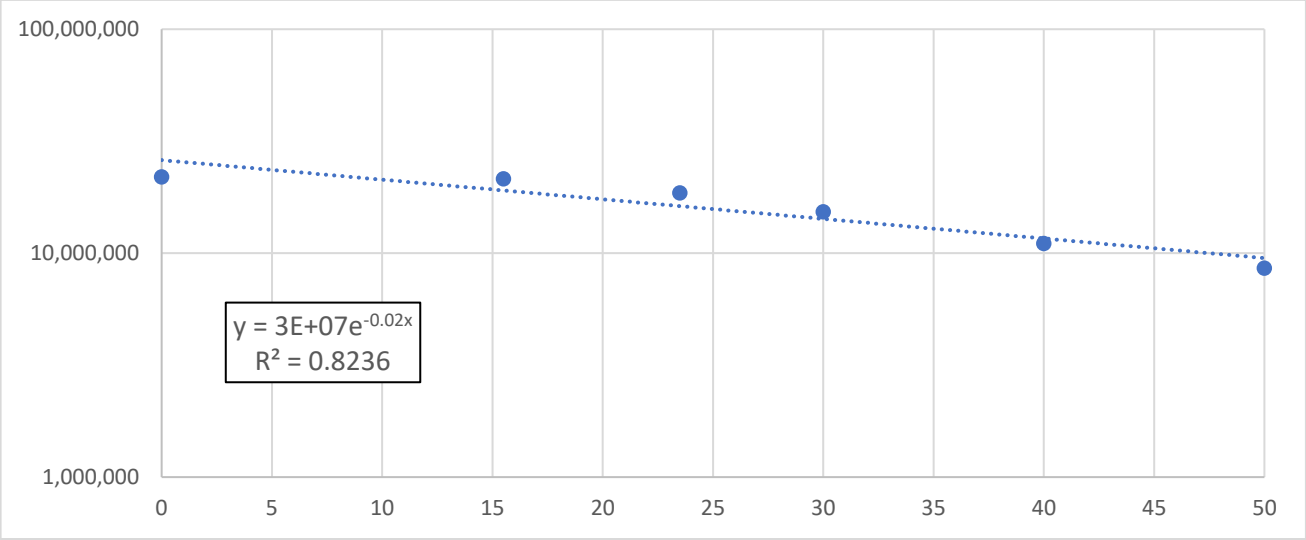
Room Chamber 1
Room size 58.8 m^3

10/01/2022

Validation R1 n = 1

Mean Plate Count	Time (mins)	Room Count
149,000	0	21,903,000
146,000	15.5	21,462,000
126,500	23.5	18,595,500
104,000	30	15,288,000
75,150	40	11,047,050
58,350	50	8,577,450

	1 hour trend
Exponent	-0.020
Intercept	6.00E+07
Calculated 60' count	1.81E+07
Log_{10} Reduction	0.52

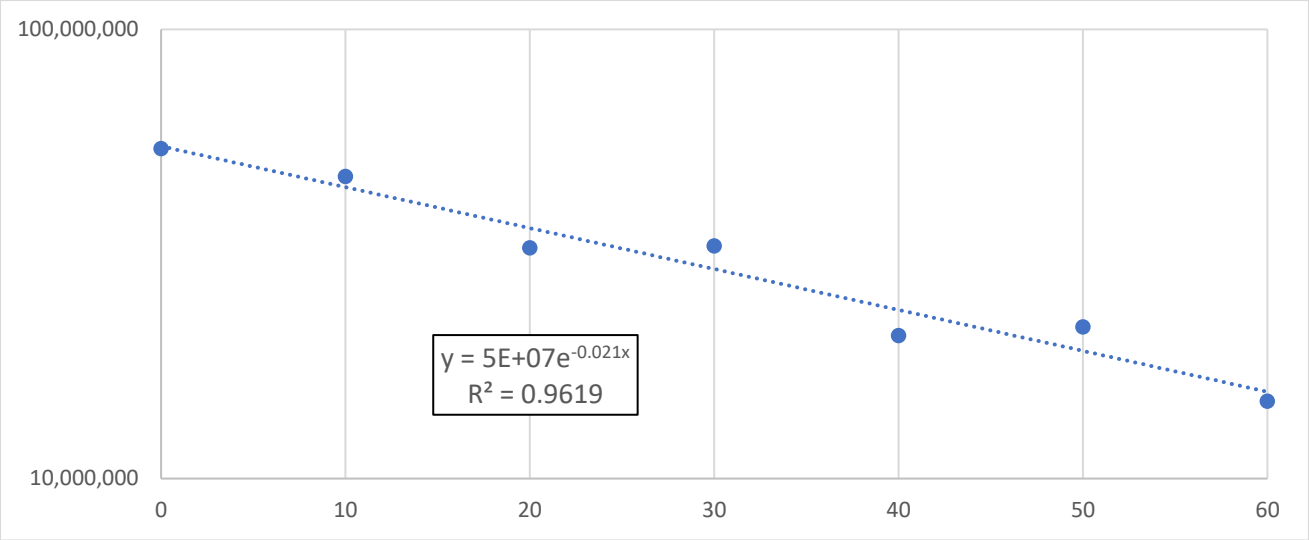


24/01/2022

Validation R1 n = 2

Mean Plate Count	Time (mins)	Room Count
184,500	0	54,243,000
160,000	10	47,040,000
111,000	20	32,634,000
112,000	30	32,928,000
70,750	40	20,800,500
73,950	50	21,741,300
50,600	60	14,876,400

	1 hour trend
Exponent	-0.021
Intercept	6.00E+07
Calculated 60' count	1.70E+07
Log_{10} Reduction	0.55

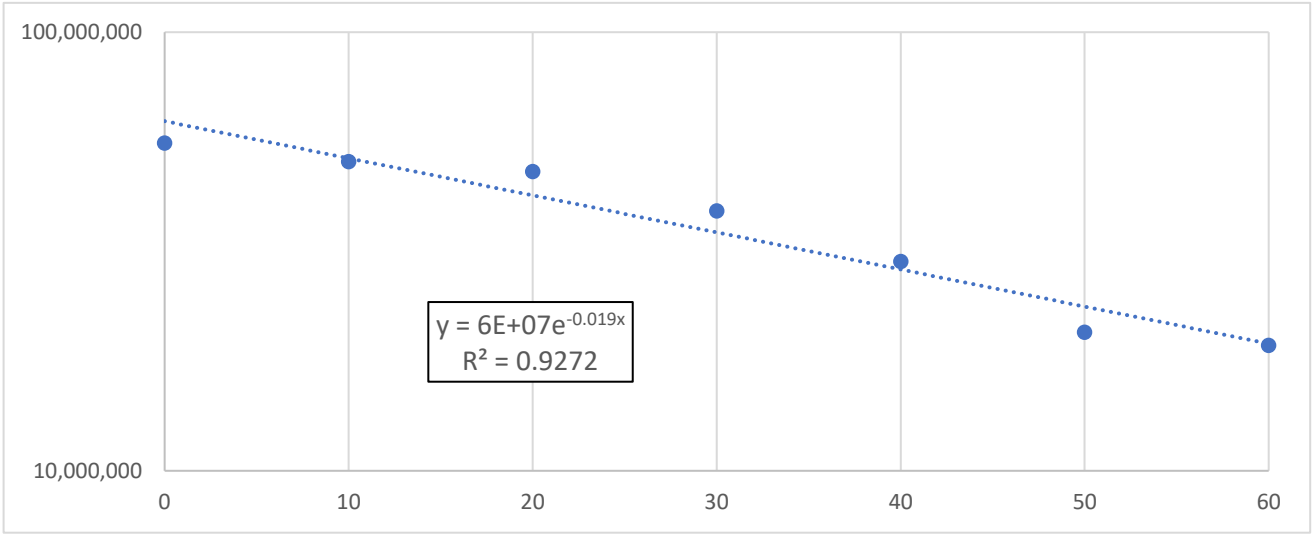


02/02/2022

Validation R1 n = 3

Plate Count 1	Plate Count 2	Time (mins)	Room Count
165,000	215,000	0	55,860,000
169,000	176,000	10	50,715,000
157,000	170,000	20	48,069,000
135,000	131,000	30	39,102,000
98,100	106,000	40	30,002,700
75,900	64,800	50	20,682,900
67,200	64,200	60	19,315,800

	1 hour trend
Exponent	-0.019
Intercept	6.00E+07
Calculated 60' count	1.92E+07
Log_{10} Reduction	0.50

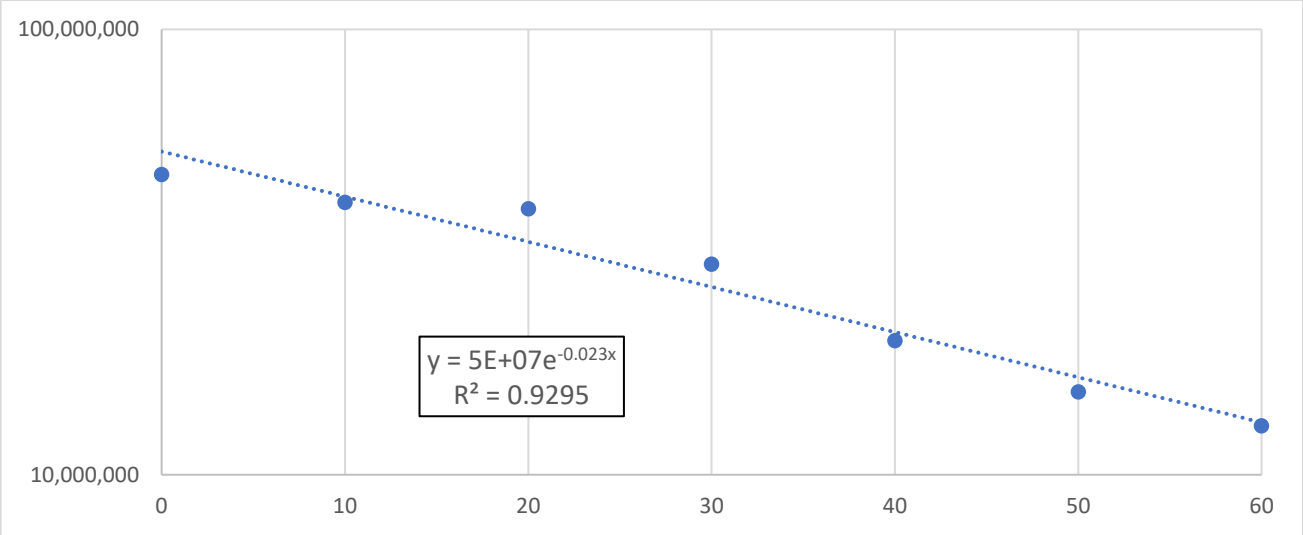


03/02/2022

Validation R1 n = 4

Plate Count 1	Plate Count 2	Time (mins)	Room Count
169,000	152,000	0	47,187,000
135,000	143,000	10	40,866,000
115,000	154,000	20	39,543,000
100,000	102,000	30	29,694,000
73,000	63,000	40	19,992,000
52,600	51,800	50	15,346,800
46,000	41,600	60	12,877,200

	1 hour trend
Exponent	-0.023
Intercept	5.00E+07
Calculated 60' count	1.26E+07
Log_{10} Reduction	0.60

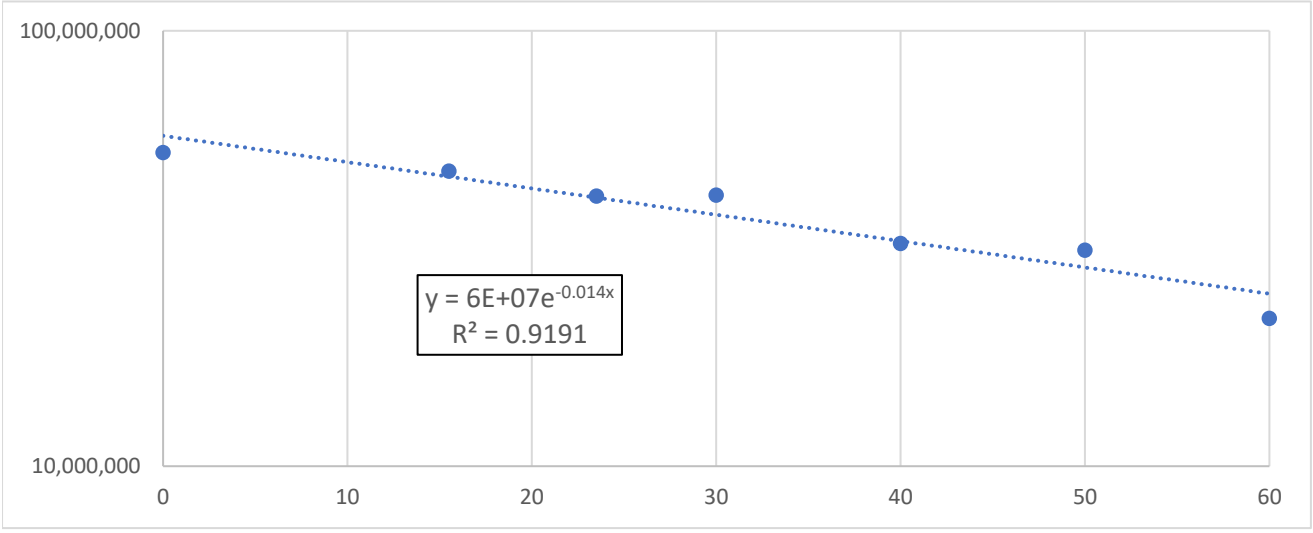


27/04/2022

Validation R1 n = 5

Plate Count 1	Plate Count 2	Time (mins)	Room Count
176,000	181,000	0	52,479,000
163,000	161,000	15.5	47,628,000
128,000	156,000	23.5	41,748,000
157,000	128,000	30	41,895,000
119,000	102,000	40	32,487,000
117,000	96,300	50	31,355,100
74,100	74,500	60	21,844,200

	1 hour trend
Exponent	-0.014
Intercept	6.00E+07
Calculated 60' count	2.59E+07
Log_{10} Reduction	0.36

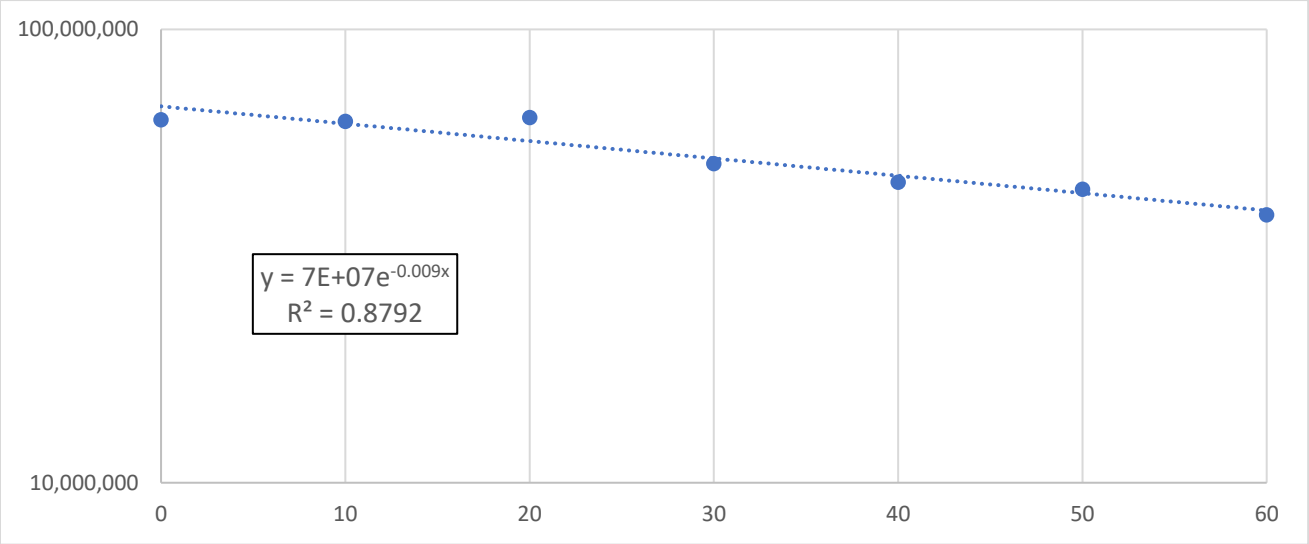


04/05/2022

Validation R1 n = 6

Plate Count 1	Plate Count 2	Time (mins)	Room Count
219,000	211,000	0	63,210,000
196,000	230,000	10	62,622,000
231,000	204,000	20	63,945,000
174,000	170,000	30	50,568,000
144,000	169,000	40	46,011,000
146,000	156,000	50	44,394,000
119,000	146,000	60	38,955,000

	1 hour trend
Exponent	-0.009
Intercept	7.00E+07
Calculated 60' count	4.08E+07
Log_{10} Reduction	0.23

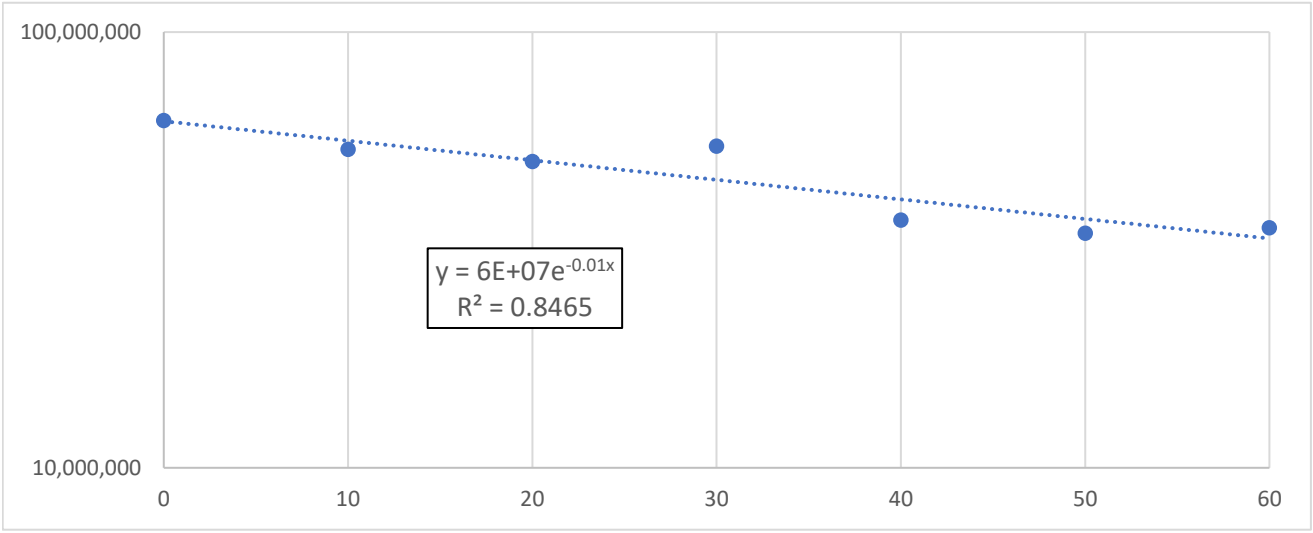


05/05/2022

Validation R1 n = 7

Plate Count 1	Plate Count 2	Time (mins)	Room Count
200,000	226,000	0	62,622,000
181,000	185,000	10	53,802,000
174,000	169,000	20	50,421,000
185,000	187,000	30	54,684,000
122,000	130,000	40	37,044,000
126,000	109,000	50	34,545,000
133,000	109,000	60	35,574,000

	1 hour trend
Exponent	-0.010
Intercept	6.00E+07
Calculated 60' count	3.29E+07
Log_{10} Reduction	0.26

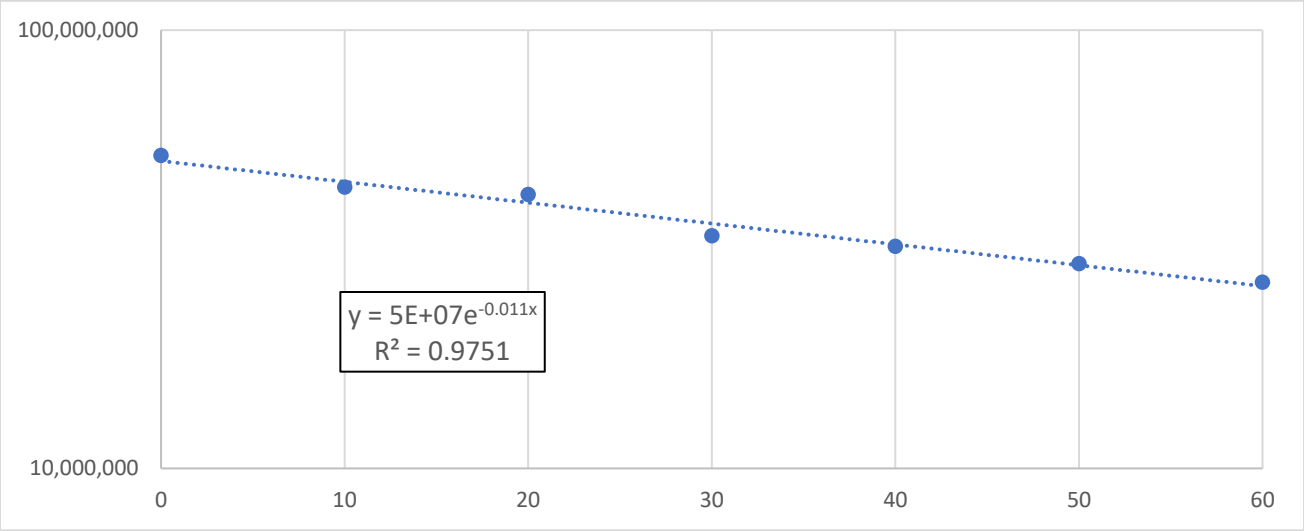


17/05/2022

Validation R1 n = 8

Plate Count 1	Plate Count 2	Time (mins)	Room Count
167,000	185,000	0	51,744,000
150,000	148,000	10	43,806,000
128,000	159,000	20	42,189,000
107,000	124,000	30	33,957,000
92,600	126,000	40	32,134,200
92,600	107,000	50	29,341,200
84,700	96,300	60	26,607,000

	1 hour trend
Exponent	-0.011
Intercept	5.00E+07
Calculated 60' count	2.58E+07
Log_{10} Reduction	0.29



Results summary (bacterial killing curve) - natural decay

Log_{10} reduction over an hour in a 58.8 m^3 chamber

Unnormalised results

n=1	0.52
n=2	0.55
n=3	0.50
n=4	0.60
n=5	0.36
n=6	0.23
n=7	0.26
n=8	0.29
Mean	**0.41**
SD	**0.15**

For and on behalf of the Innovation Agency
17.07.2022, Dr Nicholas Rhodes PhD & Prof Anthony Fisher PhD MD

Nicholas P. Rhodes