NOVAERUS
Airborne Infection Control

INDEPENDENT VALIDATION REPORT FOR **NOVAERUS AIR TREATMENT SYSTEMS**

NHS

NHS Clinical Trial Summary

- The trial was awarded to Novaerus for winning the prestigious Smart Solutions for HAI's award, ahead of 240 entrants.
- It was conducted in the Royal Free Hospital in London, by the United Kingdom Government Department of Health.
- Royal Free Hospital is a famous teaching hospital with 900 Beds that treats 700,000 patients annually.
- During the trial, 8,500+ samples were taken over 4 months, from 21 locations (both surface and air).
- Dr. Edward James, Consultant Microbiologist oversaw the trial along with 2 full time microbiologists and 1 full time government bio-statistician who tracked the data.
- Results were compared against both internal and external 'control' data.

Key Findings

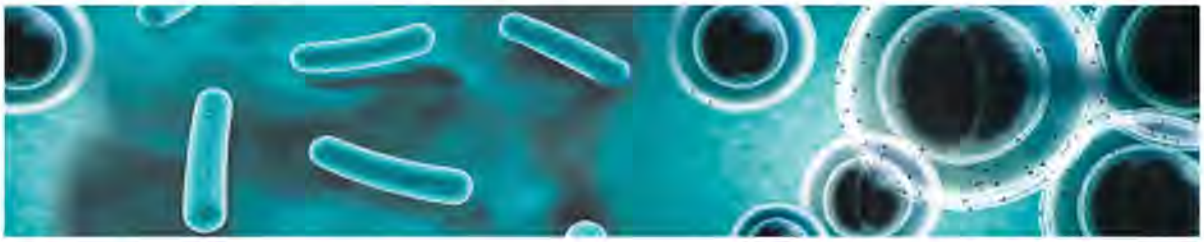
- NOVAERUS was considered by Ward Staff to be generally acceptable and easy to use.
- For Environmental Surface TVC, values were 49% lower with the device switched on when compared to the internal control (device off).
- For Environmental Surface MRSA, the odds of a MRSA occurrence with the device on was 3% (i.e. 97% reduction) of its internal control (device off).
- For Environmental Air MRSA, the odds of MRSA occurrence with NOVAERUS switched on were a quarter of that observed for the external control.

Primary Finding

MRSA – You are 97% less likely to have MRSA outbreak if you use Novaerus "The odds of an MRSA occurrence with the device on was 15% of that in the external control location, but with the device off, the odds of an occurrence of MRSA was 4 times of that in the external control location. In contrast, the odds of a MRSA occurrence with the device on was 3% of its internal control (device off), which was a statistically significant finding."

Secondary Finding

Surface Count Reduction – Novaerus reduced Total Viable Counts of surface bacteria by 23% on average for low heights (units on the floor) and 68% for high heights (units on table). Hence we always recommend installation of our units about 2/3rds up from the floor.



STUDY REPORT

Evaluation of Air Decontamination Technology: NOVAERUS NV-100 Airborne Infection Control Technology

Development Phase:	NHS Service Evaluation
Investigational Products:	Novaerus NV-100 Airborne Infection Control Technology
Sponsor:	Smart Solutions for HCAI *Trus*TECH® Innovation Unit Manchester Royal Infirmary, Manchester M13 9WL Smart Solutions is a national programme run by *Trus*TECH® and supported by the NHS National Innovation Centre on behalf of the Department of Health's HCAI Technology Innovation Programme
Sponsor Contact:	Dr Bryan Griffiths Programme Manager
Companies:	NOVAERUS - 470 Atlantic Avenue, 4th Floor, Boston MA 02210 - Oyster Point, Blackrock, Dublin, Ireland
Company Contacts:	Kevin Maughan - CEO John Grondin, VP – North America
NHS Trust:	Royal Free Hampstead NHS Trust
Principal Investigator:	Dr Edward James, Consultant Microbiologist
Study Dates:	June to September 2009
Report Date:	27 September 2010
Authors:	The report was prepared on behalf of Smart Solutions for HCAI by Remo, Southampton, UK

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GLOSSARY OF TERMS AND ABBREVIATIONS

AD	Air decontamination
CFU	colony forming unit
CCFT	close coupled field technology
HCAI	healthcare associated infections
IEC	Independent Ethics Committee
NHS	National Health Service
NRES	National Research Ethics Committee
MRSA	meticillin-resistant *Staphylococcus aureus*
SAB	Sabouraud dextrose agar
SD	standard deviation
TVC	total viable count
VOC	volatile organic compound

1 SYNOPSIS

Title of the Study: Evaluation of Air Decontamination Technology: NOVAERUS NV-100 Airborne Infection Control Technology
Investigators: Dr Edward James, Consultant Microbiologist, Royal Free Hampstead NHS Trust
Study Location(s): General medical/elderly care wards at the Royal Free Hospital, Pond Street, Hampstead NW3 2QG
Publication (reference): None
Study dates: June to September 2009
Objectives: • To assess the effect on environmental microbial load of deploying air decontamination devices in a general ward environment. • To compare the efficacy of these devices during the test period. • To assess ease of use and acceptability of air decontamination devices in a general ward environment.
Methodology: This was an open study conducted at the Royal Free Hospital, London (Royal Free and Hampstead NHS Trust) to evaluate three different air decontamination devices, including NOVAERUS NV-100 Airborne Infection Control Technology. This report describes the evaluation of Novaerus. The evaluations of the other two devices (AD [air decontamination] unit manufactured by Inov8 Science Ltd, and Medixair manufactured by Pathogen Solutions Ltd and distributed by GE Healthcare) are described in two further reports. Four-bedded bays and single rooms of general medical/elderly care wards were used for the study. Each device was trialled over a 16 week period divided into five periods as follows: Period 1 2 weeks Devices off (baseline data collection) Period 2 5 weeks Devices on Period 3 2 weeks Devices off Period 4 5 weeks Devices on Period 5 2 weeks Devices off Devices were placed in three bays/rooms and a fourth bay/room acted as a control (no device present). The exact location and number of floor areas used for the study was dependant on the bed use at the time. The standard cleaning regimen for the wards was not to be modified in any way during the duration of the study and any changes were recorded. The sampling protocol was adhered to where ever possible for the 16 week study duration. Where ever possible the same personnel performed the sampling. The presence of any patients colonised with alert organisms was recorded by sampling staff. Results of hand hygiene audits for the duration of the study were to be made available to the study team to ensure that hand hygiene compliance had been comparable throughout the study. A total of 21 standardised sites for surface sampling were identified in the 4-bedded bays. The 21 sampling sites consisted of 12 high surfaces (from above waist/table top height to tops of doors or windows) and 9 low surfaces (from below waist/table top height to floor level). Each of the sites was sampled 5 times per week, alternating between morning pre-cleaning and afternoon post-cleaning. Therefore for each of the devices a total of 105 samples were collected per week. Up to 17 standardised sites were identified in the single rooms for surface sampling (9 high surfaces and 8 low surfaces). Each site was sampled 5 times per week, alternating between morning pre-cleaning and afternoon post-cleaning, making a total of 85 samples collected per week for each of the devices Surface Sampling was by contact agar plates for determining total viable count (TVC) and meticillin-resistant *Staphylococcus aureus* (MRSA). *Clostridium difficile* and Enterobacteriaceae were measured if positive patients had been identified in the locations used in the study.

Up to 6 air samples were taken per day, 4 times weekly in each bay and room. Samples were collected for TVC, fungi (Sabouraud dextrose agar, SAB) and MRSA. Air sampling was performed using AirTrace slit-to-agar microbial air sampler. A total of 200 L of air was sampled per plate. C. *difficile* and Enterobacteriaceae were measured if positive patients were identified in the bays or rooms. Surface contact agar plates and plates from air sampling were cultured and read in the Microbiology Department of the Royal Free Hospital using standard methodology. Bacterial counts were expressed as colony forming units (CFU). A standardised questionnaire was used to obtain feedback regarding the devices.
Number Evaluated: For Novaerus, 2666 samples were analysed for environmental surface TVC and 4732 samples were analysed for environmental surface MRSA. A total of 379 samples were analysed for environmental air TVC, 364 samples for MRSA and 384 samples for environmental air fungi.
Test Product(s): Novaerus NV-100 Airborne Infection Control Technology, destroys pathogenic particles in air including microbes and volatile organic compounds (VOCs). The manufacturer claims that it also reduces airborne odours.
Statistical methods: Due to the high level of zero or low counts, the original data (measures of colony forming units, CFU) were skewed. Therefore prior to analysis, data were either log-transformed or converted to a binary outcome. Regression techniques were used in the analysis; either linear regression after log transformation (environmental surface and air TVC, and air fungi) or logistic regression after transformation to binary data (environmental surface and air MRSA). In the analyses two comparisons were performed: the effect of Novaerus (on or off) compared with the external control (bay or room without a device), and the effect of Novaerus switched on compared to its internal control (device switched off). For environmental surface TVC the location (bay and room) and height of measurement (low and high) were considered in the analyses. For environmental surface MRSA duration (24 and 48 hours after device switched on or off) was considered. For environmental air TVC, MRSA and fungi (SAB) the location (bay and room) was considered in the analyses. Odds ratios with their corresponding 95% confidence interval (CI) were calculated for each comparison, as was the P-value. For the comparison of device vs external control, a ratio >1 suggested a higher count of organisms with a device present (on or off) compared with the external control; a ratio <1 suggested a lower count with a device present compared with the external control. For the comparison of device on versus off (internal control), a ratio >1 suggested a higher count of organisms with a device on compared with off, and a ratio <1 suggested a lower count with a device on compared with off. A P-value <0.05 indicated statistical significance.

Results: Evaluation of NOVAERUS NV-100 Airborne Infection Control Technology, placed in general medical/elderly care wards of the Royal Free Hospital, suggests that the effect of the device was mainly observed as a reduction in surface contamination.

The findings indicated that Novaerus reduced environmental TVCs on low and high surfaces in single rooms, but only on high surfaces in 4-bedded bays. It is noted that these findings were statistically significant for the comparison of the device with the internal control but not with the external controls.

The 24 hour environmental surface MRSA data suggest that the device may reduce occurrences of environmental surface MRSA. The odds of a MRSA occurrence with the device on was 15% of that in the external control location, but with the device off, the odds of an occurrence of MRSA was 4 times of that in the external control location (only the latter finding was statistically significant). In contrast, the odds of a MRSA occurrence with the device on was 3% of its internal control (device off), which was a statistically significant finding.

It is considered that the inconsistencies in the differences between the device and the external control could have been due to underlying differences between the locations, and not simply due to the presence or absence of the device. Additionally, the relationship with cleaning status (whether a sample had been taken pre- or post-cleaning, although this was done alternately) may have had a bearing on the results. The internal comparison of the device on versus off provided an alternative confirmatory method of analysis. However, further investigations of Novaerus, particularly with regard to controls, are required in order to fully establish the effect of this device on environmental pathogens that are potential sources of infection in the hospital ward setting.

Regarding feedback from ward staff, the results showed that generally Novaerus was acceptable. Overall six of the seven respondents (five nurses, one pathway coordinator and one healthcare assistant) indicated that the device did not increase the level of noise.

Conclusions:

- Novaerus was most effective at reducing environmental surface contamination in patient 4-bedded bays and single rooms.
- Novaerus was considered by ward staff to be generally acceptable and easy to use.

Date of the report: 27 September 2010

2 ETHICS

The National Research Ethics Committee (NRES) was consulted to determine whether or not the project required ethical approval. The NRES confirmed that the project was not of the type that required ethical review and approval by a NHS Research Ethics Committee.

3 INVESTIGATORS AND STUDY ADMINISTRATIVE STRUCTURE

This evaluation of air decontamination devices was sponsored by *Trus*TECH® Innovation Unit, Manchester Royal Infirmary, Manchester M13 9WL, as part of the Smart Solutions for healthcare associated infections (HCAI) programme.

The study took place within wards of the Royal Free Hospital, Royal Free Hampstead NHS Trust, Pond Street, Hampstead, London NW3 2QG. The principal investigator was Dr Edward James, Consultant Microbiologist, Royal Free Hampstead NHS Trust, working with the Trust's infection control team.

Kerry Williams, clinical scientist at the Royal Free Hospital was involved in collection and recording of samples from the decontamination sites and conducting the microbial analysis.

The programme manager at Smart Solutions for HCAI was Dr Bryan Griffiths

Paul Bassett of Statsconsultancy Ltd, Amersham, Bucks HP7 9EN, performed the data analysis.

This report was prepared on behalf of Smart Solutions by Remo, Southampton, SO14 3FJ.

4 STUDY OUTLINE

4.1 Programme Background

As part of continued efforts by the Department of Health to control infection within the NHS, a programme of evaluating technologies with the potential to further reduce levels of infection is in progress.

Smart Solutions for HCAI is a national programme run by *Trus*TECH®, The North West of England NHS Innovations Hub, on behalf of the Department of Health's HCAI Technology Innovation Programme, and supported by the NHS National Innovation Centre. Smart Solutions aims to bring forward new technologies generated by businesses in healthcare or other commercial sectors that are not currently in use, or have not been widely adopted, within the NHS, but have the potential to be transferred into the NHS to help reduce infection. Nine new technologies were selected for evaluation in the Smart Solutions for HCAI programme following a national competition in 2008.

This report describes the evaluation of Novaerus, manufactured by Quest International (UK) Ltd. The evaluations of the other two devices (Inov8 AD [air decontamination] unit manufactured by Inov8 Science Ltd, and Medixair manufactured by Pathogen Solutions Ltd) are described in two further reports. Additionally, there is a composite report of all three devices.

4.2 Technological Background

Novaerus uses it's patented technology to destroy particles in air including microbes and volatile organic compounds (VOCs). The manufacturer claims that it also reduces airborne odours. The product is currently used in the food, aerospace, agricultural industries and other sectors where bio-security, bio-integrity and emission controls are paramount.

4.3 Study Rationale

A variety of methods are used to deep clean and decontaminate hospital wards, and no single product or technology may be appropriate in the fight to reduce infection. Therefore, it was important to explore the use of different or new technologies that either improve or complement existing procedures. Consequently, in this study portable devices for destroying airborne pathogens were tested with the potential to complement other methods of infection control such as hand hygiene and deep cleaning of surfaces.

4.4 Benefit-Risk and Hazard Evaluation

No potential health and safety risks to either patients or healthcare personnel were identified for the devices to be tested.

The devices were supplied with all necessary health and safety certificates.

5 STUDY OBJECTIVES

The study objectives were:

- To assess the effect on environmental microbial load of deploying air decontamination devices in a general ward environment.
- To compare the efficacy of these devices during the test period.
- To assess ease of use and acceptability of air decontamination devices in a general ward environment.

6 INVESTIGATIONAL PLAN

6.1 Method

This was an open study conducted at the Royal Free Hospital, London (Royal Free and Hampstead NHS Trust).

6.1.1 Schedule and Room Location

Four-bedded bays and single rooms of general medical/elderly care wards were used for the study. Each air decontamination device was trialled over a 16 week period divided into five periods as follows:

Period 1	2 weeks	Devices off	(baseline data collection)
Period 2	5 weeks	Devices on	
Period 3	2 weeks	Devices off	
Period 4	5 weeks	Devices on	
Period 5	2 weeks	Devices off	

Devices were placed in three bays/rooms and a fourth bay/room acted as a control (no device present). The exact location and number of floor areas used for the study was dependant on the bed use at the time.

The standard cleaning regimen for the wards was not to be modified in any way during the duration of the study and any changes were recorded.

6.1.2 Microbial Sampling

The sampling protocol was adhered to where ever possible for the 16 week study duration. Where ever possible the same personnel performed the sampling. The presence of any patients colonised with alert organisms was recorded by sampling staff. Results of hand hygiene audits for the duration of the study were to be made available to the study team to ensure that hand hygiene compliance had been comparable throughout the study.

6.1.2.1 Surface Sampling

A total of 21 standardised sites for surface sampling were identified in the 4-bedded bays (Figure 1). The 21 sampling sites consisted of 12 high surfaces (from above waist/table top height to tops of doors or windows) and 9 low surfaces (from below waist/table top height to floor level). Each of the sites was sampled 5 times per week, alternating between morning pre-cleaning and afternoon post-cleaning. Therefore for each of the devices a total of 105 samples were collected per week.

Up to 17 standardised sites were identified in the single rooms for surface sampling (9 high surfaces and 8 low surfaces) (Figure 2). Each site was sampled 5 times per week, alternating between morning pre-cleaning and afternoon post-cleaning, making a total of 85 samples collected per week for each of the 3 devices

Surface Sampling was by contact agar plates for determining total viable count (TVC) and meticillin-resistant *Staphylococcus aureus* (MRSA). *Clostridium difficile* and Enterobacteriaceae were measured if positive patients had been identified in the bays or rooms used in the study.

6.1.2.2 Air Sampling

Up to 6 air samples were taken per day, 4 times weekly in each bay and room (Table 1).

At each sampling contact agar plates were collected for TVC, fungi (Sabouraud dextrose agar, SAB) and MRSA. Air sampling was performed using AirTrace® slit-to-agar microbial air sampler. A total of 200 L of air was sampled per plate. *C difficile* and Enterobacteriaceae were measured if positive patients were identified in the bays or rooms.

Table 1: Air decontamination study sample collection

Location	Samples	Surface samples (Total viable count and MRSA)	
4-bed bay	High contact surfaces	12	
	Low contact surfaces	9	
	Sampling episodes	5	
	Total per week	105	
Single room	High contact surfaces	9	
	Low contact surfaces	8	
	Sampling episodes	5	
	Total per week	85	
		Air samples	
		Total viable count and fungi: 2 plates x 6 time points per day x 4 times per week	**MRSA: 4 plates x 6 time points per day x 4 times per week**
4-bed bay	Total samples per week	48	96
Single room	Total samples per week	48	96

6.1.3 Ease of Use and Acceptability of Devices

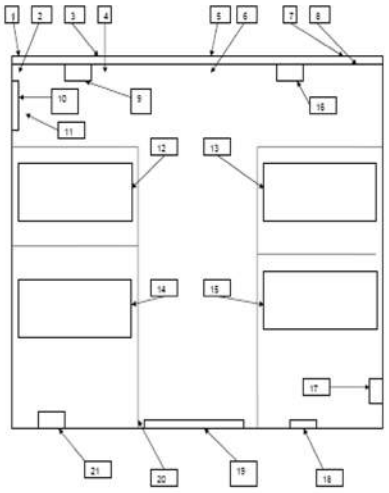
A standardised questionnaire was used to obtain feedback from ward personnel regarding the devices (**Error! Reference source not found.**).

Following completion of the study, usability of the devices was assessed by interviews with key clinical, cleaning and facilities management staff. This was to determine if the devices had any other effects on the test area (eg reduction in odour, increase in noise etc).

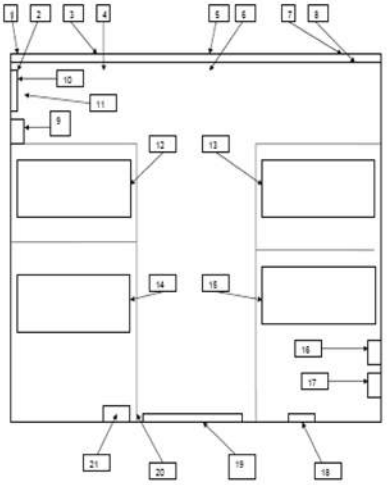
See section 8.5.

Figure 1: Locations of surface sampling sites in 4-bedded days

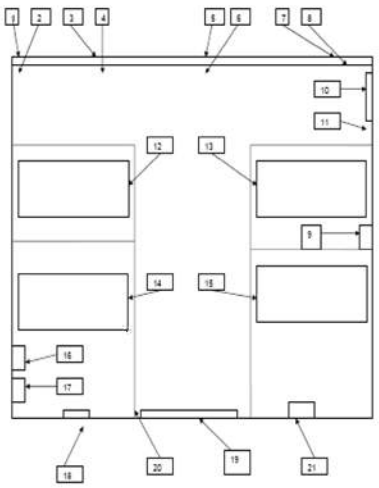
Bay 1, 7 South



Bay 8, West Beds 5 to 8



Bay 2, 8 West

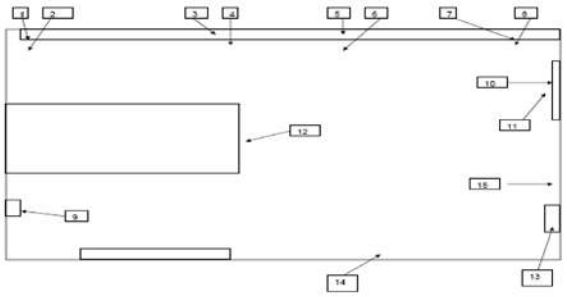


Key:

1. end window ledge
2. end window floor
3. off centre window ledge
4. off centre window floor
5. 2nd off centre window ledge
6. 2nd off centre window floor
7. 2nd end window ledge
8. 2nd end window floor
9. 1st medicine locker
10. toilet door frame
11. toilet door floor
12. under 1st bed head
13. under 2nd bed head
14. under 3rd bed head
15. under 4th bed head
16. 2nd medicine locker
17. 3rd medicine locker
18. top of paper towel holder
19. bay door frame
20. curtain rail holder
21. 4th medicine locker

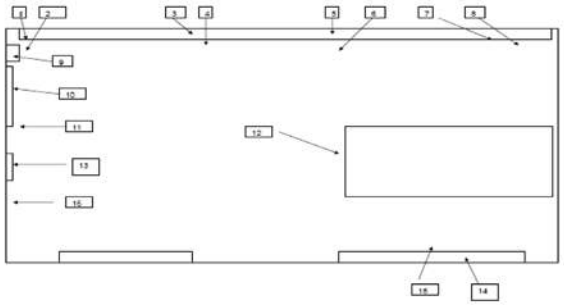
Figure 2: Locations of surface sampling sites in single rooms

7 South Room 1



Key:
1. End window ledge
2. End window floor
3. Off centre window ledge
4. Off centre window floor
5. 2nd off centre window ledge
6. 2nd off centre window floor
7. 2nd end window ledge
8. 2nd end window floor
9. medicine locker
10. toilet door frame
11. toilet door floor
12. under bed head
13. top of paper towel holder
14. floor between door and hand basin
15. floor between hand basin and toilet door

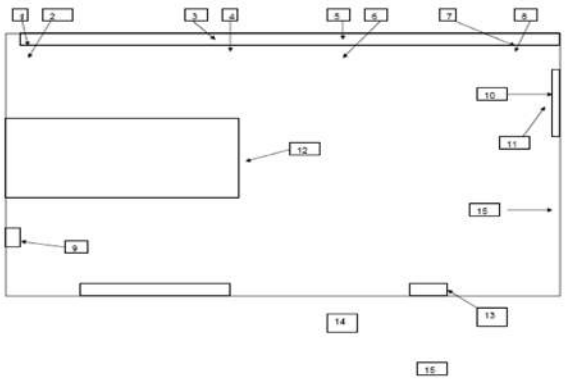
7 South Room 2



Key:
1. End window ledge
2. End window floor
3. Off centre window ledge
4. Off centre window floor
5. 2nd off centre window ledge
6. 2nd off centre window floor
7. 2nd end window ledge
8. 2nd end window floor
9. medicine locker
10. toilet door frame
11. toilet door floor
12. under bed head
13. top of paper towel holder
14. internal window frame
15. internal window floor
16. floor between room door and toilet door

Figure 2 continued: Locations of surface sampling sites in single rooms

8 West Room 2



Key:
1. End window ledge
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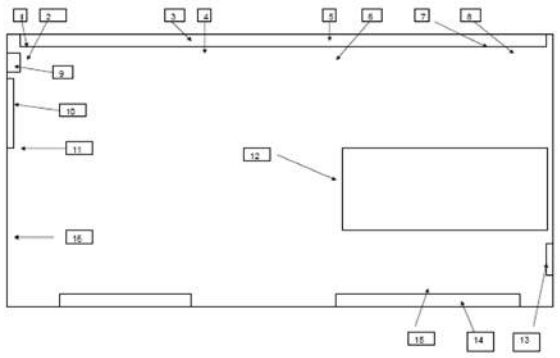
5. 2nd off centre window ledge
6. 2nd off centre window floor
7. 2nd end window ledge
8. 2nd end window floor
9. medicine locker
10. toilet door frame
11. toilet door floor
12. under bed head
13. top of paper towel holder
14. floor between door and hand basin
15. floor between hand basin and toilet door

8 West Room 1



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9. medicine locker
10. toilet door frame
11. toilet door floor
12. under bed head
13. top of paper towel holder
14. internal window frame
15. internal window floor
16. floor between room door and toilet door

6.2 Discussion of Study Design

This was an open study designed to be conducted in the real-life environment of hospital wards of a busy London NHS Trust. General medical/elderly care wards of the Royal Free and Hampstead NHS Trust were selected as the location for this study.

Both single-bed rooms and 4-bed bays were chosen as locations to evaluate the devices to provide some indication of the effect of room size.

Because the effect of a device may vary with height of surfaces to be decontaminated, sampling sites for testing for environmental bacteria were categorised as high (greater than waist height) and low (less than waist height). For surface testing a variety of objects were tested in order to obtain a wide cross section of places that may be contaminated including floors, window ledges, window frames, under bed heads, door frames, medicine lockers and paper towel holders.

The effects of a device were assessed in comparison with two types of control, both an external control (single-bed rooms or 4-bed bays with no device), and an internal control (a device switched off).

The statistical power of the study was estimated from pre-baseline data from 4 weeks of testing on wards with no air decontamination devices present. The sample size was estimated by computing aggregated measures of the microbial measures to create simplified endpoints for each sampling episode over a 2 week period with no treatment.

6.3 Investigational Product(s)

This report describes the use of Novaerus.

Novaerus uses it's patented technology to destroy particles in air including microbes and volatile organic compounds (VOCs). The manufacturer claims it can also be used to reduce odour. The product is currently used in the food, aerospace, agricultural industries and other sectors where bio-security, bio-integrity and emission controls are paramount. Novaerus is manufactured by Novaerus, Oyster Point, Blackrock, Dublin, Ireland.and supplied by Novaerus US Inc, 470 Atlantic Avenue, 4th Floor, Boston. MA 02210.

7 STUDY ASSESSMENTS

7.1 Microbiology

Samples collected on contact agar plates (surface sampling) and during air sampling were cultured and read in the Microbiology Department of the Royal Free Hospital using standard methodology. The bacterial counts were expressed as colony forming units (CFU) per 1000 L of air.

7.1.1 Ease of Use and Acceptability of Devices

Feedback from ward personnel regarding the devices was collated and summarised. See section 8.5.

7.2 Quality Assurance

Accurate records were to be maintained by the device operatives and those personnel collecting and analysing the samples. These were copied to the principal

investigator for verification. Standard report forms were used to record all information.

7.3 Statistical Methods

Full details of the statistical analyses are provided in the Statistical Report. (Appendix 3)

7.3.1 Analysis Strategy and Methods

The design of the study was an interrupted design, such that in the different locations, the air decontamination device was switched on for set periods of time and off (internal control) for set periods of time (see Section 6.1). In addition to the location with the device, there was also a control set of measurements taken from 4-bed bays and single rooms that had no device present (external control).

Therefore the two possible comparisons of the data were between a location with a device present and its external control, and between a device switched on and its internal control (device switched off).

The outcome variables (see below) were measured as the number of CFU per 1000 litres of air. The effect of the device upon the CFU values was analysed using regression methods, either linear regression or logistic regression.

A complicating factor in the data analysis was that samples were taken multiple times from each location over the study period. Therefore, it was likely that the results from an individual location would be more similar than the results from different locations. Consequently, data values were not 'independent' of each other. To allow for this, robust standard errors were used with the regression analyses.

The regression analyses included adjustments for surface height (low or high). The analyses examined the interaction between height and device on/off. A significant interaction between these two variables implied that the effects of the devices were different for low and high surface heights, and the two heights were then analysed separately. If there was no interaction for surface height, the two heights were combined in the analyses.

The odds ratios with their corresponding 95% confidence interval (CI) were calculated for each comparison, as was the P-value. For the comparison of a location with a device with its external control, a ratio >1 suggested a higher count of organisms with a device present compared with the external control; a ratio <1 suggested a lower count with a device present compared with the external control. For the comparison of a device on versus off (internal control), a ratio >1 suggested a higher count of organisms with a device on compared with off, and a ratio <1 suggested a lower count with a device on compared with off. A P-value <0.05 indicated statistical significance.

7.3.1.1 Environmental Surface Total Viable Count

A feature of the environmental surface TVC data was that some CFU counts were above the upper detection limits. For these counts, an estimated CFU value was attributed based on the Dip readings.

An examination of the distribution of the data indicated that they were highly skewed in their distribution, with a preponderance of smaller values, and a few higher values. The data were therefore log transformed. Whilst not totally normalising the values, this made the distribution more normal, and allowed the data to be analysed on a continuous scale, using linear regression. The data were analysed for bays for both

low and high surface heights (interaction found), and for rooms and for heights combined (no interaction found).

7.3.1.2 Environmental Surface MRSA

For the first three weeks of data collected, environmental surface MRSA counts were measured after 24 hours on each day. After this time, counts from each day were measured at both 24 hours and 48 hours. Therefore, two separate outcomes at 24 and 48 hours were considered. As no measurements at 48 hours were collected for the first 3 weeks, this time period was omitted from the analysis of the 48 hour data.

An examination of the environmental MRSA values indicated that for the vast majority of data points, no MRSA was found. Therefore, the data had an extremely skewed distribution, with the majority of values either zero or very low counts. For this reason, the data were presented using the binary outcome of MRSA present or MRSA not present was created and analysed using logistic regression.

Preliminary analysis showed that the low environmental surface MRSA also meant a formal analysis for bays and rooms separately could not be performed, and the two locations were combined, as were the two surface heights.

7.3.1.3 Environmental Air Total Viable Count

At each site environmental air TVC measurements were made by using two AirTrace® slit-to-agar microbial air samplers. In theory the two machines should have provided identical results, but there were instances when the results were quite varied. When the measurements differed by over 50%, and by over 50 CFU/L, they were omitted from the analysis. However, this accounted for less than 2% of all measurements.

As with the surface TVC, the air TVC measurements were found to have a positively skewed distribution. Therefore, these were also log-transformed and analysed using linear regression. Separate analyses were performed on bays and rooms.

7.3.1.4 Environmental Air MRSA

The vast majority of environmental air MRSA measurements were made at 48 hours. However, for the first 4 days of data collection measurements were only made at 24 hours. To ensure an unbiased analysis of the data, the 24 hours values were omitted from the analysis, and so the analysis was only performed on the 48 hour data.

The analysis of this outcome followed a similar strategy to that of surface MRSA, and categorised into the binary outcome of MRSA present or not. Logistic regression was used to compare the occurrence of MRSA when the device was on and off, and also to compare between devices. As there were so few occurrences of environmental MRSA there were insufficient data to examine rooms and bays separately, and so these were combined for the purposes of analysis.

7.3.1.5 Environmental Air Fungi count (SAB)

As with the other outcomes, the environmental air fungi measurements had a highly skewed distribution. The data were log-transformed to allow for analysis on a continuous scale, although still demonstrating a slightly skewed distribution. The analysis was performed on bays and rooms using linear regression.

7.3.2 Sample Size

Statistical power was determined from pre-baseline data (ie 4 weeks testing on wards with no units present). For the purposes of sample size estimation simplified endpoints of computing aggregated measures of the microbial measures for each sampling episode over a 2 week period with no treatment were used:

Endpoint	Mean	Between sample SD
% TVC>50	17.1%	11.5%
Mean MRSA	0.72	1.07
Mean Fungi (SAB)	0.13	0.16

It was estimated that 10 weeks of active sampling in each of two rooms with 5 samples per week would yield 100 samples. The additional sampling periods were to allow adjustment to be made for differences between rooms.

For sample size estimation a simple t-test at a significance level of 0.15 (to allow for multiple testing) was assumed.

7.4 Changes in the Conduct of the Study Including Changes to the Planned Analyses

There were no changes.

8 RESULTS

8.1 Data Sets Analysed

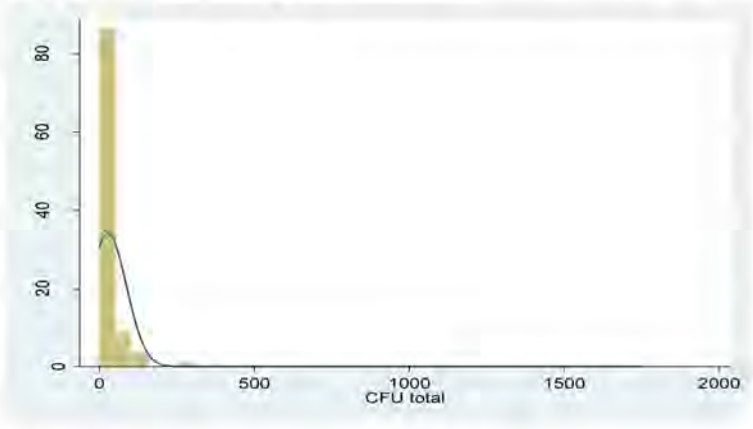
Over the 16-week period of the evaluation of Novaerus, 2666 samples were analysed for environmental surface TVC and 4732 samples were analysed for environmental surface MRSA. A further 379 samples were analysed for environmental air TVC, 364 samples for MRSA and 384 samples for environmental air fungi.

8.2 Summary of Data

All data for the five variables tested in this study showed a strong positive skew, with most values at the lower end of the scale and few high values. Histograms plots of these data (all CFU values pooled from locations both with the device and external control locations) are shown in Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7. The graphs also show the log-transformation of the environmental surface TVC, environmental air TVC, and environmental air fungi. Environmental surface MRSA and environmental air MRSA - which as a proportion of total counts (TVC) little was detected – were presented as binary outcomes.

Figure 3: Distribution of environmental surface TVC CFU values for Novaerus – A: original scale; B: log scale

A



B

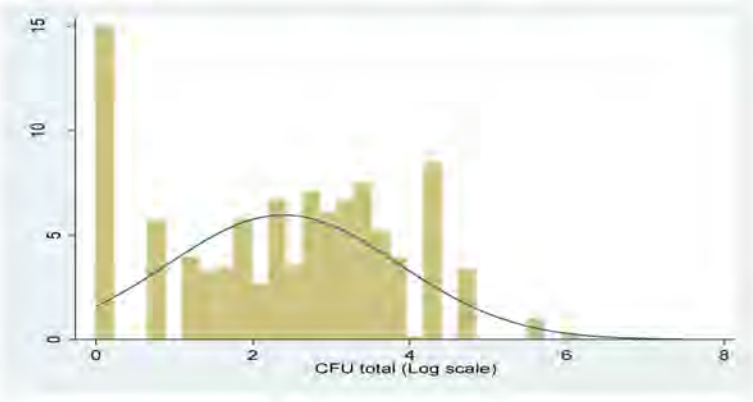


Figure 4: Distribution of environmental surface MRSA for Novaerus (original scale)

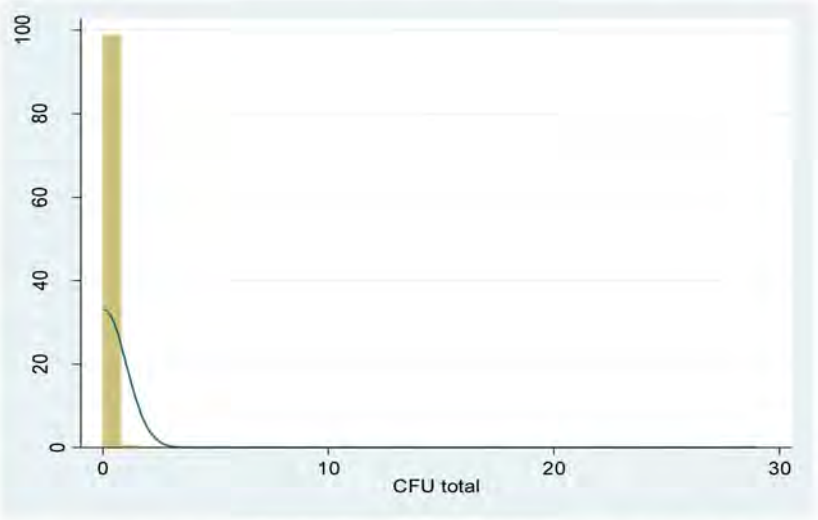
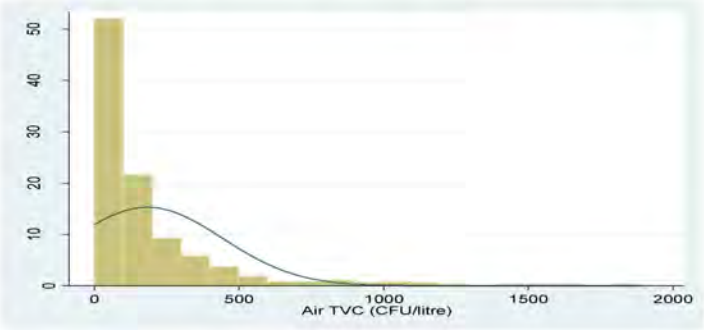


Figure 5: Distribution of environmental air TVC with Novaerus – A: original scale; B: log scale

A



B

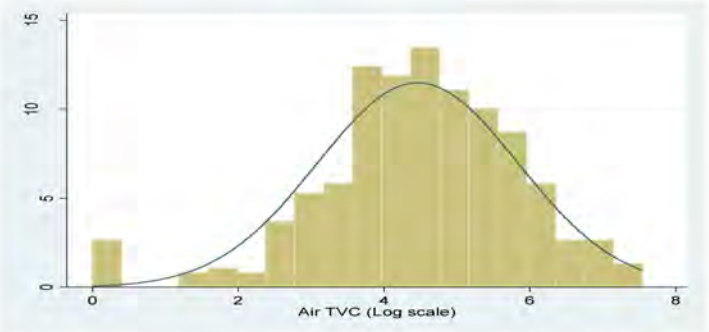


Figure 6: Distribution of environmental air MRSA for Novaerus (original scale)

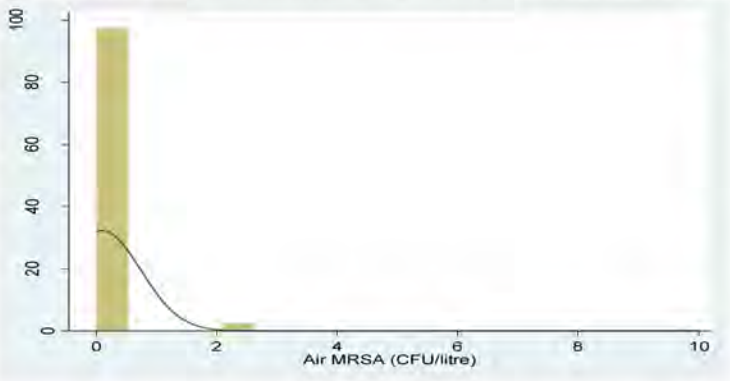
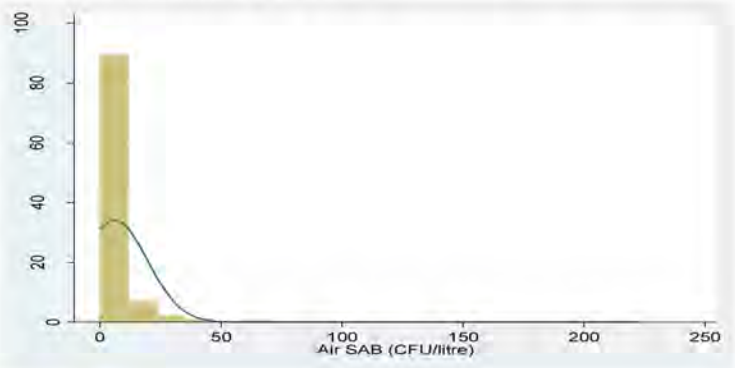
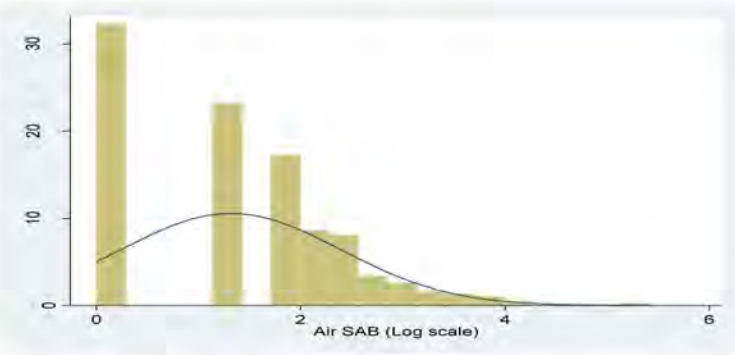


Figure 7: Distribution of SAB counts (environmental air fungi) for Novaerus – A: original scale; B: log scale

A



B



Mean CFU values (original and transformed data – log or binary scale) are summarised for each variable in Table 2, Table 3, Table 4, Table 5 and Table 6. Additionally, a plot of the mean daily TVC over time (on the original scale of measurement) for the device switched on (red) and switched off (blue) is in Figure 8.

Table 2: Summary of environmental surface TVC CFU values for Novaerus

Location	Device	Device Status	Original scale Mean (SD)	Log scale Mean (SD)
Bays	Control	All	36 (133)	2.5 (1.5)
	Novaerus	Device off	38 (64)	2.9 (1.4)
		Device on	31 (77)	2.5 (1.5)
Rooms	Control	All	35 (120)	2.0 (1.7)
	Novaerus	Device off	21 (44)	2.2 (1.4)
		Device on	18 (34)	2.0 (1.4)
Bays& Rooms Combined	Control	All	35 (128)	2.3 (1.6)
	Novaerus	Device off	31 (57)	2.6 (1.4)
		Device on	26 (63)	2.3 (1.5)

Figure 8: Environmental surface mean daily TVC CFU values over time for locations with Novaerus and external controls

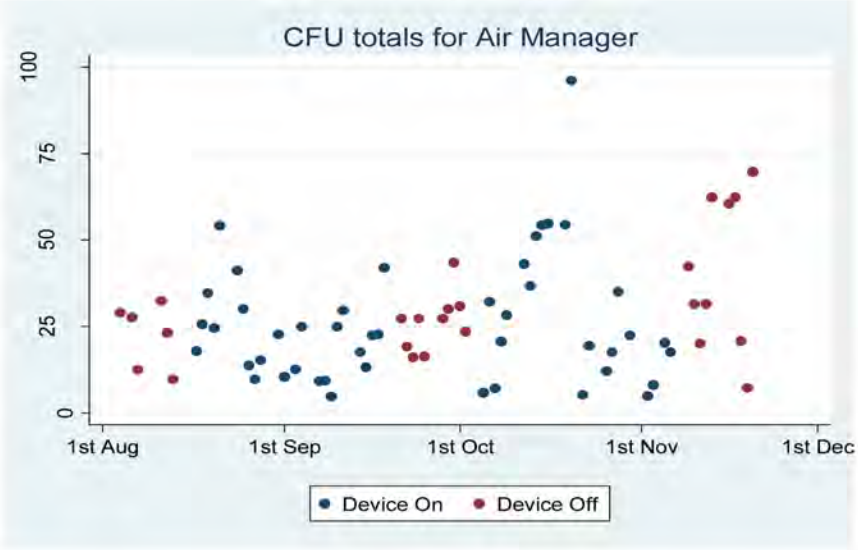


Table 3: Summary of environmental surface MRSA CFU counts for Novaerus

Time	Device	Device Status	Original scale Mean (SD)	Counts >0 Number (%)
24 hours	Control	All	0.01 (0.27)	10 (0.4%)
	Novaerus	Device off	0.04 (0.44)	16 (1.7%)
		Device on	0.01 (0.52)	1 (0.1%)

Table 4: Summary of environmental air TVC for Novaerus

Location	Device	Device Status	Air TVC Original scale Mean (SD)	Air TVC Log scale Mean (SD)
Bays	Control	All	204 (226)	4.8 (1.1)
	Novaerus	Device off	233 (305)	4.8 (1.4)
		Device on	200 (243)	4.7 (1.3)
Rooms	Control	All	108 (121)	4.1 (1.2)
	Novaerus	Device off	198 (333)	4.4 (1.2)
		Device on	126 (170)	4.1 (1.3)
Bays & rooms combined	Control	All	156 (187)	4.5 (1.2)
	Novaerus	Device off	216 (318)	4.6 (1.4)
		Device on	163 (213)	4.4 (1.3)

Table 5: Summary of environmental air MRSA for Novaerus

Location	Device	Device Status	Air MRSA Original scale Mean (SD)	Air MRSA Counts > 0 n (%)
Bays	Control	All	0.20 (0.78)	13 (6.7%)
	Novaerus	Device off	0.04 (0.31)	1 (1.6%)
		Device on	0.11 (0.94)	2 (1.7%)
Rooms	Control	All	0.29 (1.45)	10 (5.5%)
	Novaerus	Device off	0.04 (0.31)	1 (1.6%)
		Device on	0.13 (0.55)	6 (5.0%)
	Control	All	0.25 (1.16)	23 (6.3%)
Bays & rooms combined	Novaerus	Device off	0.04 (0.12)	2 (1.6%)
		Device on	0.12 (0.77)	8 (3.4%)

Table 6: Summary of environmental air fungi (SAB counts) for Novaerus

Location	Device	Device Status	Original scale Mean (SD)	Log scale Mean (SD)
Bays	Control	All	5.7 (11.3)	1.3 (1.1)
	Novaerus	Device off	5.4 (6.6)	1.4 (1.0)
		Device on	5.3 (8.4)	1.3 (1.1)
Rooms	Control	All	5.0 (7.0)	1.3 (1.0)
	Novaerus	Device off	8.8 (26.4)	1.4 (1.2)
		Device on	5.2 (8.8)	1.2 (1.1)
Bays & rooms combined	Control	All	5.3 (9.44)	1.3 (1.0)
	Novaerus	Device off	7.1 (19.3)	1.4 (1.1)
		Device on	5.3 (8.6)	1.3 (1.1)

8.3 Comparison of Novaerus with External Control

8.3.1 Environmental Surface Total Viable Count

The results of the regression analysis of log transformed TVC CFUs comparing Novaerus with external controls are in Table 7. For bays there was a significant interaction with height, suggesting a difference between Novaerus and external control for low and high surfaces. For low surfaces no significant difference was observed for either Novaerus switched on or off when compared with the external control. For high surfaces there was a small indication that the numbers of TVC CFUs were higher when the device was switched off than in the external control, although this result was only of borderline statistical significance. There was no difference between Novaerus switched on and the control for high surfaces. The results indicated no significant interaction with height for rooms, suggesting that the effects of the device were the same for both low and high surfaces. For rooms there was no significant difference between the device switched on or off and the external control.

Table 7: Environmental surface TVCs comparing Novaerus with external control; results of linear regression

Location	Device	Surface Height	Comparison	Ratio (95% CI) (Device/ext ctrl)	P-value
Bay	Novaerus	Low	Device off vs ext ctrl	1.07 (0.84, 1.36)	0.58
			Device on vs ex ctrl	0.94 (0.79, 1.11)	0.43
		High	Device off vs ext ctrl	1.86 (0.98, 3.48)	0.05
			Device on vs ex ctrl	1.14 (0.58, 2.25)	0.70
Room	Novaerus	All heights	Device off vs ext ctrl	1.18 (0.83, 1.68)	0.35
			Device on vs ex ctrl	0.99 (0.72, 1.35)	0.93

8.3.2 Environmental Surface MRSA

The results of the logistic regression of environmental surface MRSA CFU for Novaerus on or off versus the external control are in

Table 8. No interaction between Novaerus and sampling height was observed, suggesting that the effect of Novaerus on surface MRSA was similar for both low and high surfaces. The heights were therefore combined for the analysis. For the 24 hour measurements a significantly higher occurrence of MRSA was observed with Novaerus switched off compared with the external control (P <0.001). The odds of an occurrence of MRSA were 4 times higher when Novaerus was switched off compared to the external control. In contrast, the odds of an occurrence of MRSA with Novaerus switched on were 15% of the external control.

Table 8: Environmental surface MRSA comparing Novaerus with external control; results of logistic regression

Location	Device	Time (hours)	Surface height	Comparison	Odds Ratio (95% CI) (Device/Ext ctrl	P-value
Bays & rooms combined	Novaerus	24	All heights	Device off vs ext ctrl	4.39 (2.27, 8.52)	<0.001
				Device on vs ext ctrl	0.15 (0.02, 1.05)	0.06
		48	All heights	Device off vs ext ctrl	0.55 (0.29, 1.03)	0.06
				Device on vs ext ctrl	0.90 (0.52, 1.54)	0.70

8.3.3 Environmental Air Total Viable Count

Results of the linear regression used in the comparison of surface TVC values with Novaerus relative to those in the external control are in Table 9. The results indicated no difference between Novaerus (on or off) and the external control, for both bays and rooms.

Table 9: Environmental air TVC comparing Novaerus with external control; results of linear regression

Location	Device	Comparison	Ratio (95% CI) (Device/ext ctrl)	P-value
Bay	Novaerus	Device off vs ext ctrl	0.93 (0.67, 1.26)	0.60
		Device on vs ext ctrl	0.83 (0.63, 1.10)	0.19
Room	Novaerus	Device off vs ext ctrl	1.30 (0.91, 1.86)	0.15
		Device on vs ext ctrl	1.01 (0.74, 1.36)	0.97

8.3.4 Environmental Air MRSA

Logistic regression was used to compare environmental MRSA occurrence for Novaerus (both on and off) compared to the external control, and the results are summarised in Table 10. There was slight evidence of a difference in MRSA between the external control and Novaerus switched off, although the result was not statistically significant. The odds of MRSA with Novaerus switched off were a quarter of that observed for the external control. The difference in MRSA between the external control and Novaerus switched on was not statistically significant. The odds of MRSA with Novaerus switched on were a half of that observed for the external control.

Table 10: Environmental Surface MRSA for Novaerus compared to external control

Location	Device	Comparison	Odds Ratio (95% CI) (Device/ext ctrl)	P-value
Bays & Rooms combined	Novaerus	Device off vs ext ctrl	0.24 (0.06, 1.03)	0.06
		Device on vs ext ctrl	0.52 (0.22, 1.18)	0.12

8.3.5 Environmental Air Fungi Count (SAB)

Linear regression of the air SAB values for Novaerus compared with the external control is summarised in Table 11. The results for both bays and rooms suggested no evidence of a difference between Novaerus and the external control in terms of SAB values (either when the device was switched on or off).

Table 11: Environmental air fungi (SAB counts) for Novaerus compared to external control

Location		Comparison	Ratio (95% CI) (Device/ext ctrl)	P-value
Bay	Novaerus	Device off vs ext ctrl	1.08 (0.81, 1.42)	0.62
		Device on vs ext ctrl	0.98 (0.77, 1.24)	0.85
Room	Novaerus	Device off vs ext ctrl	1.14 (0.86, 1.52)	0.36
		Device on vs ext ctrl	0.91 (0.71, 1.15)	0.42

8.4 Internal Comparison of Novaerus On versus Off

8.4.1 Environmental Surface Total Viable Count

The results comparing the effect of Novaerus on versus off are in Table 12. The results indicated that, for bays with Novaerus, there was a significant interaction between height and device on or off, suggesting that the effects of Novaerus varied for low and high surfaces. For low surfaces there was no significant difference in TVC CFU values between the device on and off. For high surfaces the TVC CFU values were significantly lower (P <0.001) with the device switched on compared to off, being on average 49% lower. For rooms, there was no interaction with height, suggesting a similar effect for both high and low surfaces. The results showed that TVC CFU values were significantly lower with the device on (P = 0.03), being on average 16% lower than when the device was switched off.

Table 12: Environmental surface TVCs (presented as log transformed CFUs) comparing Novaerus on with off (internal control)

Location	Device	Height	Comparison	Ratio (95% CI) (Device on/off)	P-value
Bay	Novaerus	Low	Device on vs off	0.87 (0.73, 1.05)	0.14
		High	Device on vs off	0.61 (0.49, 0.77)	<0.001
Room		All	Device on vs off	0.84 (0.72, 0.97)	0.03

8.4.2 Environmental Surface MRSA

The results of the logistic regression of environmental surface MRSA for Novaerus on versus off (internal control) are in Table 14. The results showed that for 24 hour measurements, environmental MRSA was significantly reduced when the device was on. The odds were 3%, ie a 97% reduction in environmental MRSA when Novaerus was on (P = 0.001).

Table 13: Comparing Novaerus on with off (internal control) for occurrence of environmental surface MRSA; results of logistic regression

Location	Device	Time (hours)	Surface height	Comparison	Odds Ratio (95% CI) (Device on/off	P-value
Bays & rooms combined	Novaerus	24	All heights	Device on vs off	0.03 (0.01, 0.23)	0.001
		48	All heights	Device on vs off	1.64 (0.80, 3.83)	0.18

8.4.3 Environmental Air Total Viable Count

The results of linear regression comparing Novaerus on to off (internal control) are in Table 14. No differences between on and off were observed for either bays or rooms.

Table 14: Environmental air TVC comparing Novaerus on with off; results of linear regression

Location	Device	Comparison	Ratio (95% CI) (Device on/off)	P-value
Bay	Novaerus	Device on vs off	0.91 (0.62, 1.33)	0.62
Room		Device on vs off	0.77 (0.51, 1.18)	0.23

8.4.4 Environmental Air MRSA

The results of logistic regression comparing environmental air MRSA occurrence between device on and device off are in Table 15. No differences between the device on and off were observed.

Table 15: Environmental air MRSA comparing Novaerus on with off

Location	Device	Comparison	Odds Ratio (95% CI) (Device on/off)	P-value
Bays & Rooms combined	Novaerus	Device on vs off	2.15 (0.45, 10.3)	0.34

8.4.5 Environmental Air Fungi Count (SAB)

The comparison of SAB values when Novaerus was switched on, compared to switched off is in Table 16. The results also showed no evidence that Novaerus had a significant effect upon SAB values.

Table 16: Environmental air fungi (SAB counts) comparing Novaerus on with off (internal control)

Location	Device	Comparison	Ratio (95% CI) (Device on/off)	P-value
Bay	Novaerus	Device on vs off	0.91 (0.67, 1.23)	0.54
Room		Device on vs off	0.79 (0.57, 1.10)	0.16

8.5 Device Ease of Use and Acceptability

The feedback questionnaire responses are summarised in Table 17. The questionnaire was completed by five nurses, one healthcare assistant and one Pathway Coordinator who had Novaerus evaluated on their ward.

All staff interviewed were aware that the device was being evaluated on their ward.

For Novaerus, only one of the seven respondents thought the device reduced odour. Six of the respondents did not think that the device increased noise. One out of the seven respondents thought that Novaerus improved cleanliness.

Table 17: Summary of responses from ward staff on device feedback questionnaire

Question	Novaerus	
	Yes	No
Aware that device was being evaluated within the ward	7	
Reduction in odour in ward environment	1	6
Increase in noise	1	6
Improvement in cleanliness	1	6
Comment from patients	1	6
Comment	What was the machine for?	
Comments from staff		7
Staff interviewed:	7	
Healthcare assistant	1	
Pathway coordinator	1	
Staff nurse	5	

9 DISCUSSION AND OVERALL CONCLUSIONS

Evaluation of NOVAERUS NV-100 Airborne Infection Control Technology, placed in general medical/elderly care wards of the Royal Free Hospital, suggests that the effect of the device was mainly observed as a reduction in surface contamination.

The findings indicated that Novaerus reduced environmental TVCs on low and high surfaces in single rooms, but only on high surfaces in 4-bedded bays. It is noted that these findings were statistically significant for the comparison of the device with the internal control but not with the external controls.

The 24 hour environmental surface MRSA data suggest that the device may reduce occurrences of environmental surface MRSA. The odds of a MRSA occurrence with the device on was 15% of that in the external control but with the device off, the odds of an occurrence of MRSA was 4 times of that in the external control (only the latter finding was statistically significant). In contrast, the odds of a MRSA occurrence with the device on was 3% (i.e. 97% reduction) of its internal control (device off), which was a statistically significant finding.

It is considered that the inconsistencies in the differences between the device and the external control could have been due to underlying differences between the locations, and not simply due to the presence or absence of the device. Additionally, the relationship with cleaning status (whether a sample had been taken pre- or post-cleaning, although this was alternated) may have had a bearing on the results. The internal comparison of the device on versus off provided an alternative confirmatory method of analysis. However, further investigations of Novaerus, particularly with regard to controls, are required in order to fully establish the effect of this device on environmental pathogens that are potential sources of infection in the hospital ward setting.

Conclusions

- Novaerus was most effective at reducing environmental surface contamination in patient 4-bedded bays and single rooms.
- Novaerus was considered by Ward Staff to be generally acceptable and easy to use.
- For Environmental Surface TVC, values were 49% lower with the device switched on when compared to the internal control (device off).
- For Environmental Surface MRSA, the odds of a MRSA occurrence with the device on was 3% (i.e. 97% reduction) of its internal control (device off).
- For Environmental Air MRSA, the odds of MRSA occurrence with Novaerus switched on were a quarter of that observed for the external control.
- Further investigations to establish the effect of the Novaerus device on air decontamination within the hospital ward settings are required.