Microbiological Report

Anti-microbial performance of the Medixair UVc air sterilisation device in the sanitisation of the atmosphere in a hospital high dependency ward.

Conducted by

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In Conjunction with

BMI Hospital Group

Introduction

My name is R.D.O'Connor, I hold B.Sc.(Hons) degree in applied environmental microbiology and I am a chartered Biologist (Ci.Biol). I currently work as a practising microbiologist and C.E.O. of a UKAS accredited, DEFRA (formerly MAFF) authorised contract laboratory, capable of handling up to Class II pathogens.

The Medixair UVc air sterilisation device is manufactured by Brandenburg UK Ltd and has previously undergone extensive laboratory trials, which have demonstrated its efficiency in reducing the levels of a numerous airborne pathogens of industrial and medical significance.

This document describes the approach, the microbiological data obtained and our conclusions relating to a 2-week trial designed to determine the anti-microbial efficiency of the Medixair device in a clinical environment. This trial has been conducted according to the protocol given in appendix A, in a BMI Hospital High dependency unit.

The ward allocated for the trial comprised of several adjoined areas. The main patient area had a total volume of 248 m^3. Connected to this area were a clinical store (27.3 m^3 and a washroom (14.2 m^3). These latter two areas were connected to the main ward via a connecting door, which was open throughout the trial, and the estimate of volume makes no allowance for ***fromites***

The spaces described were serviced with an EU4/EU8 dual filtered heated air flow supply which was estimated to provide between 5 and 7 air changes per hour during the period of the trial. There was no recycling of air.

Sampling and Analysis

As described in Appendix A air sampling was conducted employing an industry standard device known as a **Cassala** unit. This device employs the technique of impacting a known volume (200 L) of air onto the surface of a sterile rotating agar plate in a manner which evenly distributes the air borne micro-organisms over the surface of an plate. Subsequent to exposure in this manner plates were incubated under optimal conditions to afford recovery of visible colonies.

All sampling was conducted twice daily, in duplicate over the complete duration of the trial at the same location point in ward. Daily duplicate samples were also taken at the external air intake point for the ward.

The agars employed in this trial were allocated to afford the recovery of a wide range of aerobic airborne bacteria and spores including airborne class II pathogens. A combination of non-selective, elective and selective solid media was employed which included;

Typtone soya agar
Violet red bile agar
Violet red bile glucose agar
Brucella medium
Rogosa agar
C.L.E.D agar
MRS agar
Baird Parker agar
DNA ase agar

And modified forms of these agars

After exposure plates were returned to out laboratory for incubation. All isolates were grouped and identified according to a scheme involving Gram stain and a series of morphological, biochemical and serological reactions.

Results

Data was collected over a two week period both in the ward and at the external point of air intake. During the first week of sampling the UVC device was not in operation thus providing data on the quality of untreated air. UVc treatment was commenced at the start of week two.

All sampling was achieved according to the agreed schedule apart from one external sample which was collected late.

All data presented in the tables below represents the mean of duplicate analysis sets for each day. The day 1 data for the first and second week represents the mean of samples taken throughout the day in the ward, in the manner described in Appendix A.

We have returned quantitative values for the levels of airborne bacteria and spores present in the ward and in the air intake flow for the two-week period.
Additionally we have employed the data obtained to illustrate the differential levels of Gram +ve and Gram –ve organisms isolated together with detailed analysis of the range and relative abundance of all genera confirmed by the identification techniques described above.

We have employed the Mann-Whitney non-parametric T-test as the statistical tool to test significances where applicable for population means .

Below we present in tabulated form the data obtained employing the scheme described above.

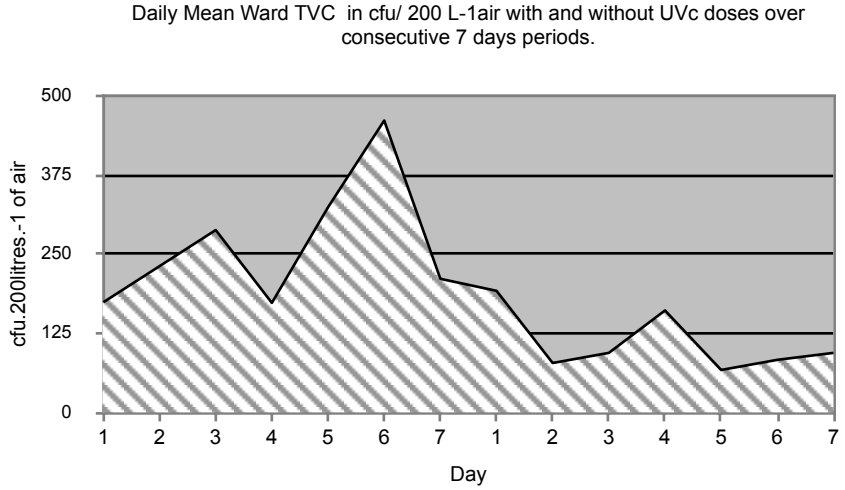
Table 1 : Mean sampling data for categories of organisms isolated from the atmosphere of a high care ward over 2 consecutive 7 day periods with and without the operation of the Medixair Uvc device

		Internal	Internal	Internal	Internal
		TVC	Gram -ve	Gram +ve	S.aureus
Day	State	cfu 200 L^{-1}	cfu 200 L^{-1}	cfu 200 L^{-1}*	cfu 200 L^{-1}*
1	OFF	174	93	81	0
2	OFF	231	176	55	0
3	OFF	288	144	144	7
4	OFF	173	87	86	0
5	OFF	324	219	105	3
6	OFF	461	303	158	11
7	OFF	211	113	98	0
1	ON	192	63	129	0
2	ON	78	24	54	0
3	ON	94	28	66	0
4	ON	161	96	65	0
5	ON	67	31	36	0
6	ON	83	48	35	0
7	ON	94	32	62	0

** confirmed bacterial isolates*

Mean UVC on	266	162	104	3
		61%	*39%*	*1%*

Mean UVC off	110	46	64	0
		42%	*58%*	*0%*



Graph 1

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Graph 2:

Graph 3:

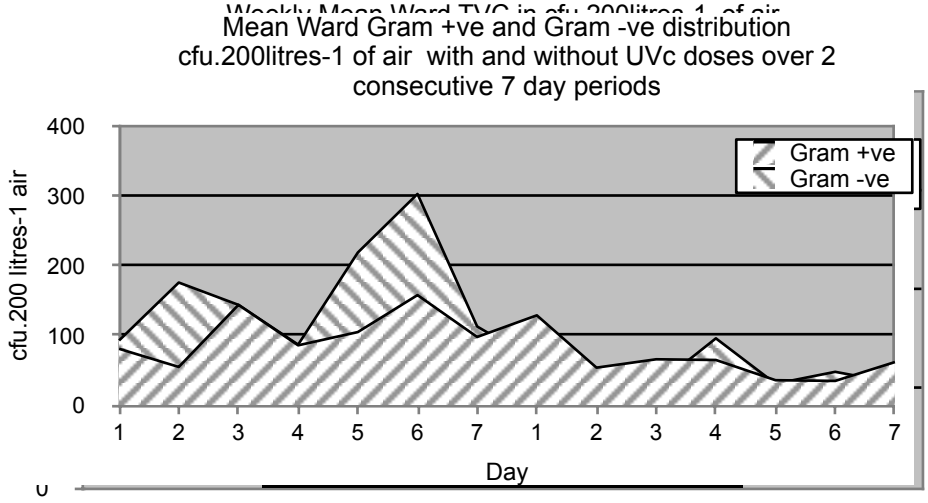


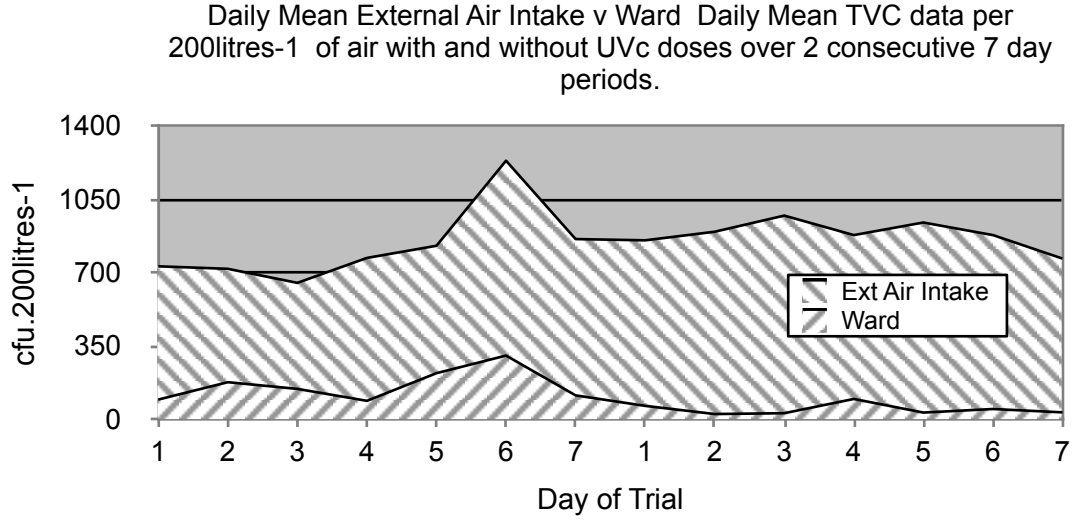
Table 2 : Mean sampling data for categories of organisms isolated from the atmosphere of a high care ward External air intake over 2 consecutive 7 day periods showing the TVC data described in Table 1

	intake	intake	intake	intake
Day	TVC cfu.200litres^{-1} *	Gram -ve cfu.200litres^{-1} *	Gram +ve cfu.200litres^{-1} *	S.aureus cfu.200litres^{-1} *
1	636	438	198	2
2	541	332	209	3
3	506	290	216	0
4	682	386	296	8
5	608	327	281	90
6	930	571	359	114
7	746	459	287	0
8	790	408	382	1
9	870	511	359	3
10	943	633	310	3
11	782	440	342	6
12	907	605	302	0
13	830	430	400	2
14	734	380	354	1

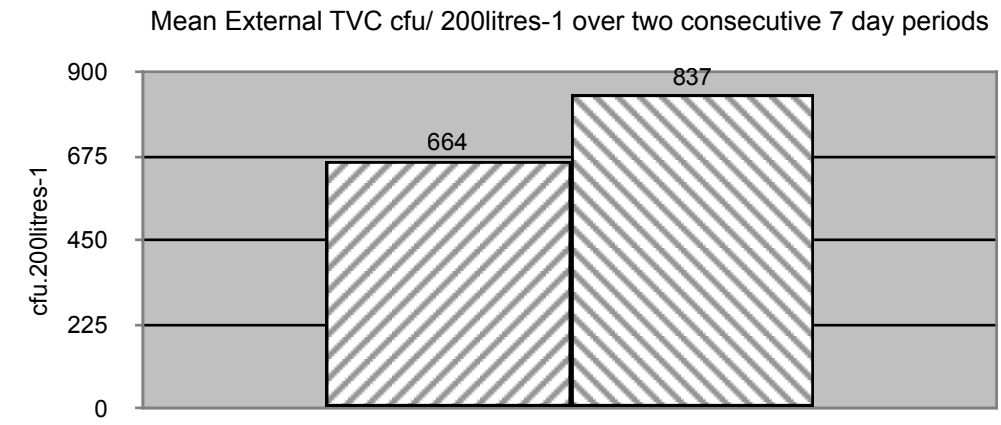
* confirmed bacterial isolates

Mean UVc off	664	400	264	31
		60%	*40%*	*5%*
Mean UVc on	837	396	290	31
		47%	*35%*	*4%*

Graph 4



Graph 5



Graph 6

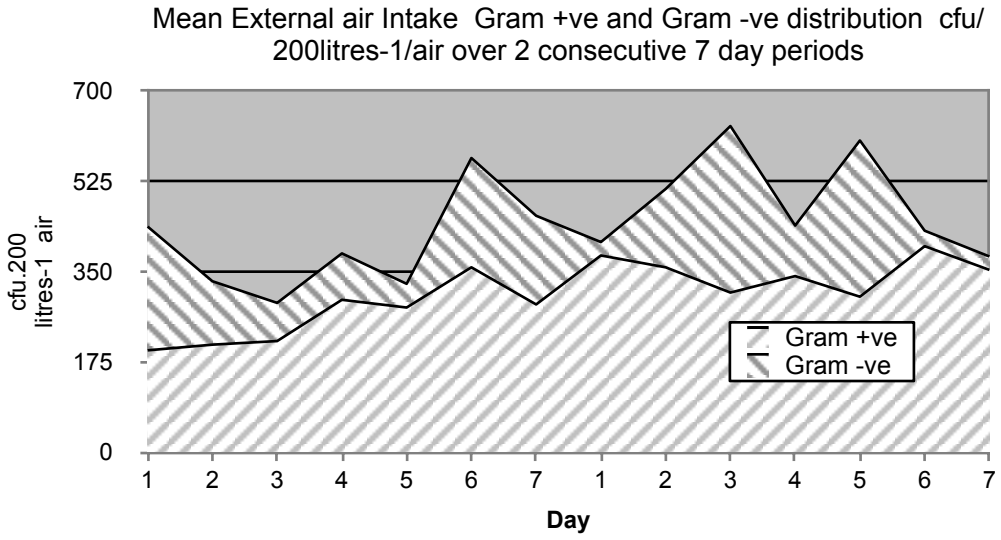
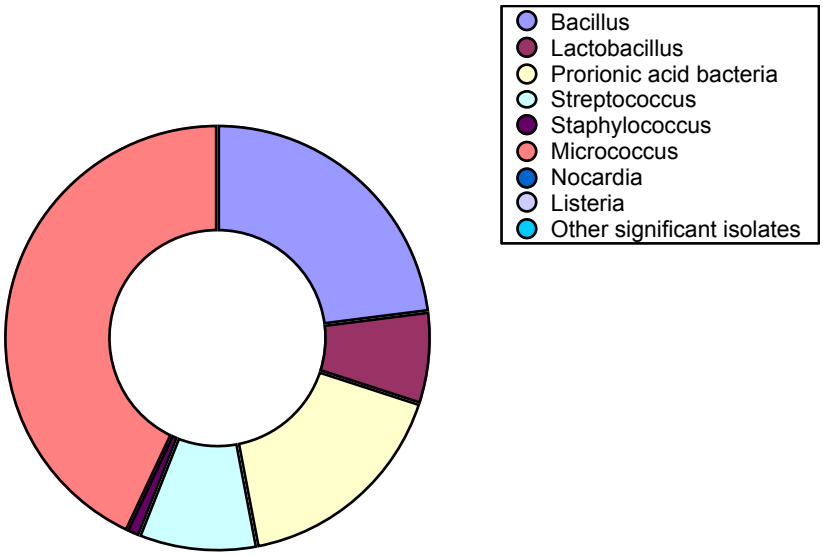


Table 3 : Mean percentages of components of the Gram +ve airborne population over 2 consecutive 7 sampling periods in the ward

Group	Percentage of Population week 1 (UVc off)	Percentage of Population week 2 (Uvc on)
Bacillus	23	31
Lactobacillus	7	9
Propionic acid bacteria	17	14
Streptococcus	9	7
Staphylococcus	1	0
Micrococcus	43	38
Nocardia	0	0
Listeria	0	0
Other significant isolates	0	0

Graph 7 Mean Gram positive population percentage component representation



Key ;

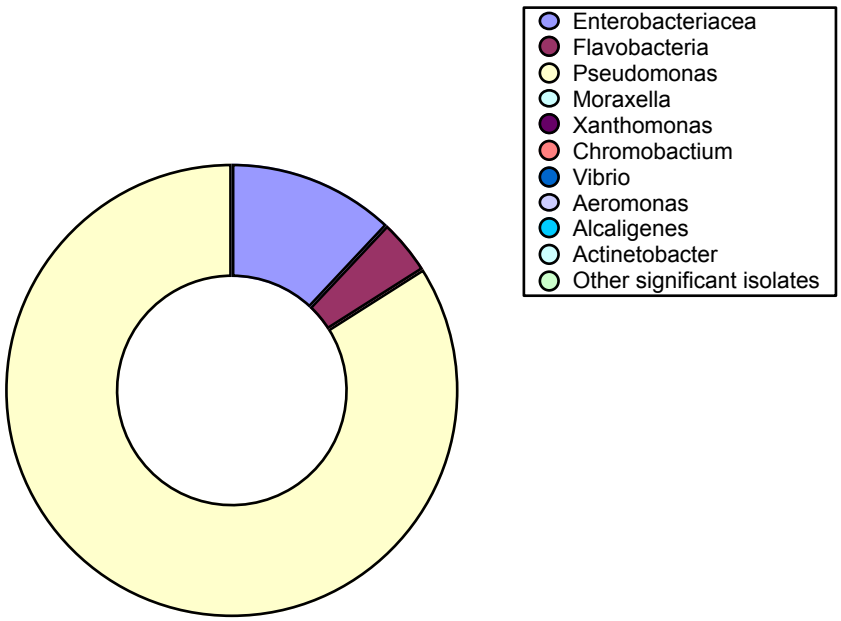
Outer circle 7 day period with no Uvc doses

Inner circle 7 day period with no Uvc doses

Table 4 : Mean percentages of components of the Gram -ve airborne population over 2 consecutive 7 sampling periods in the ward

Group	Percentage of Population week 1	Percentage of Population week 2
Enterobacteriacea	12	11
Flavobacteria	4	3
Pseudomonas	84	86
Moraxella	0	0
Xanthomonas	0	0
Chromobactium	0	0
Vibrio	0	0
Aeromonas	0	0
Alcaligenes	0	0
Actinetobacter	0	0
Other significant isolates	0	0

Graph 8 Mean Gram negative population percentage component representation



Key ;

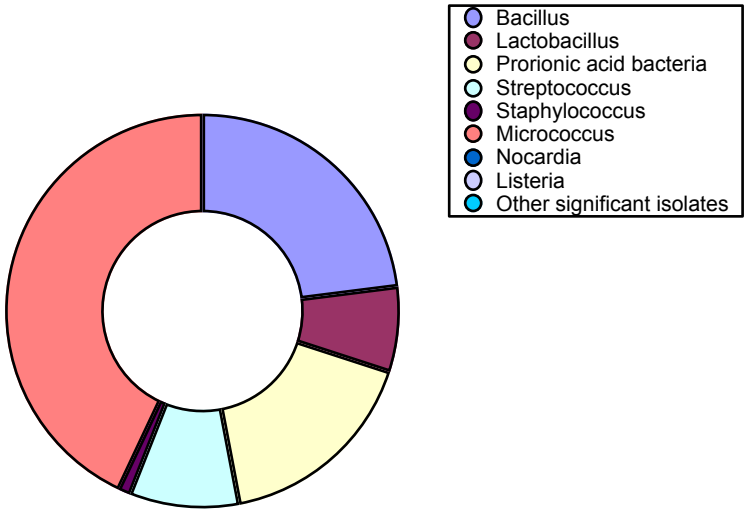
Outer circle 7 day period with no Uvc doses

Inner circle 7 day period with no Uvc doses

Table 5 : Mean percentages of components of the Gram +ve airborne population over 2 consecutive 7 sampling periods in the External intake air

Group	Percentage of Population Week 1	Percentage of Population Week 2
Bacillus	28	26
Lactobacillus	3	4
Propionic acid bacteria	21	22
Streptococcus	9	7
Staphylococcus	1	0
Micrococcus	38	41
Nocardia	0	0
Listeria	0	0
Other significant isolates	0	0

Graph 9



Key ;

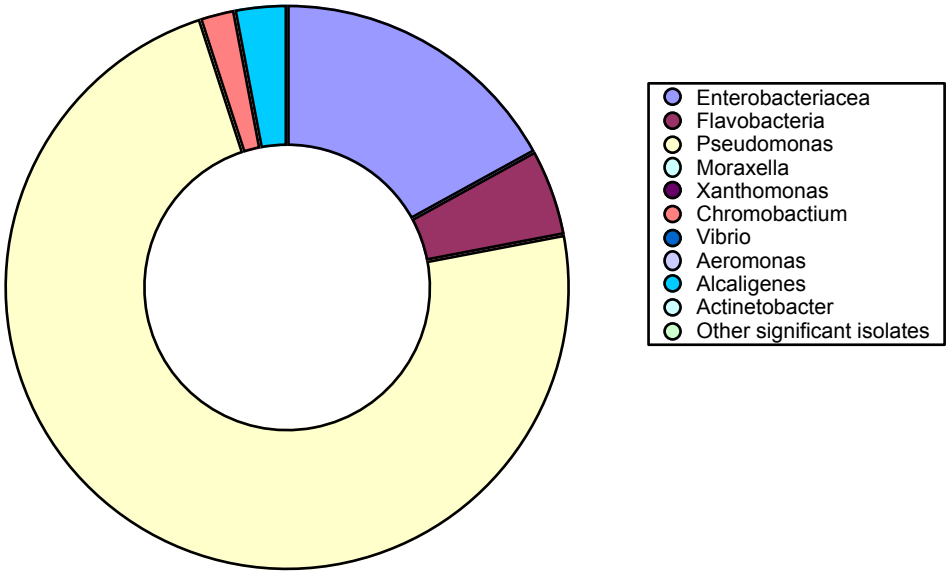
Outer circle 7 day period with no Uvc doses

Inner circle 7 day period with no Uvc doses

Table 6 : Mean percentages of components of the Gram -ve airborne population over 2 consecutive 7 sampling periods in the External intake air

Group	Percentage of Population Week 1	Percentage of Population Week 2
Enterobacteriacea	17	7
Flavobacteria	5	9
Pseudomonas	73	79
Moraxella	0	0
Xanthomonas	0	3
Chromobactium	2	2
Vibrio	0	0
Aeromonas	0	0
Alcaligenes	3	0
Actinetobacter	0	0
Other significant isolates	0	0

Graph 10



Key ;

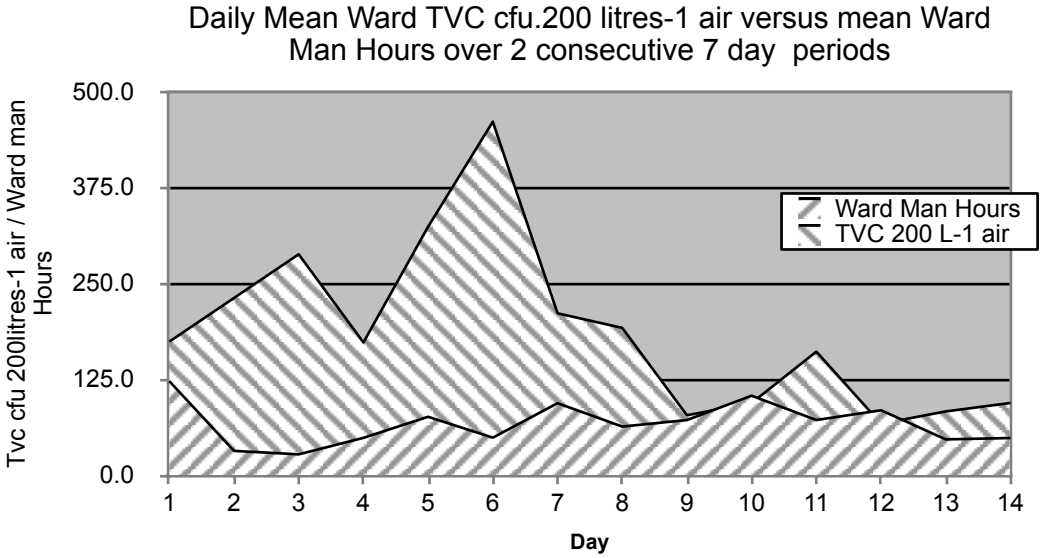
Outer circle 7 day period with no Uvc doses

Inner circle 7 day period with no Uvc doses

Table 7 : Mean sampling data for categories of organisms isolated from the atmosphere of a high care ward External air intake over 2 consecutive 7 day periods versus mean Man Ward Hours

		Internal	Internal
Day	state	TVC 200 cfu L*	Man ward Hours/day
1	OFF	174	122.5
2	OFF	231	31.5
3	OFF	288	27.0
4	OFF	173	48.5
5	OFF	324	76.0
6	OFF	461	48.8
7	OFF	211	93.8
1	ON	192	63.3
2	ON	78	71.8
3	ON	94	103.5
4	ON	161	71.8
5	ON	67	84.5
6	ON	83	46.5
7	ON	94	48.3
	Mean OFF	266	64
	Mean ON	110	70

Graph 11



Discussion

The investigation of the Medicare15 UVc air sanitation was conducted over two consecutive 7-day periods in a high care hospital ward. The device was only active during the second 7-day period. In this discussion the impact of the device on air quality, in the test environment, is discussed in terms of comparisons of microbial recoveries between periods when UVc treatment of the atmosphere was operative or not. For the sake of brevity the seven-day period when the UVc device was not

operating will be addressed as 'A' and the period when the Medixair device was operative will be addressed as 'B'.

The impact of external air quality and presence human beings in the ward is addressed in relation to the counts obtained and the range of types of organism isolated.

Data recovered for the mean Total Viable aerobic count in 200 L^{-1} of ward atmosphere for each day is presented in table 1 for both periods A and B. In the same table the respective daily mean counts for total Gram +ve and Gram -ve isolates.

In respect of the Total Viable Count data a highly significant difference exists at the 95 probability level indicating that the average daily TVC cfu/ 200L^{-1} of air for period B was lower than period A.

In considering the data obtained for Gram +ve and Gram –ve populations we also find a highly significant difference exists at the 95 probability level that the average counts for both populations is lower during the period (B) when the Medixair device was operating.

During period A (no UVc treatment) there were three (table 1) instances of isolation of coagulase positive Staphylococcus aureus from the ward atmosphere. Each event involved lower numbers of isolates and each event perhaps relatedly did correspond to the organism being present in detectable numbers in the external intake air on the day of isolation.

During period B (UVc on) no coagulase positive Staphylococcus aureus were isolated from the ward atmosphere even though Staphylococcus aureus was detected in external intake air on 6 occasions.

In relation to the data, due to the small numbers of Staphylococcal isolates involved, statistical significance tests could not be applied and therefore the data pertaining to the isolation of Staphylococcus aureus must be viewed as encouraging rather than conclusive. It is relevant, however, that statistically significant reduction of atmospheric levels was shown for Gram +ve bacteria during period B (UVc on). In particular it is relevant that the Micrococci isolated formed a significant percentage of the Gram +ve population and that our data indicates significant reduction of these organisms during period B (UVc on). Micrococci empirically show at least the same or greater resistance to UVc doses than all strains of Staphylococcus aureus, a factor which adds support to the observation made above.

Many factors are considered or known to effect the frequency of isolates in hospital atmospheric environments and it is generally accepted that applicable measuring techniques and analytical approach are still in rapid evolution. Of the known factors intake air quality and flow characteristics are considered significant. Additionally the density, status, motion patterns and dwell time of humans are known to have impact on atmospheric microbiological levels.

In this trial we have measured aspects of both the microbiological quality of the external intake air which supplied the ward and record the total accumulated ward man hours for all categories of human input for each day of the trial.

Inspection of table 7 will indicate that human traffic was not significantly different, overall for periods A and B with the average ward man hours per day being respectively 64 and 70 for weeks one and two. The trend line (Graph 11) does not track the Total Viable Count data obtained for period A or B and in fact we could show no significant numerical relationship between these or any other microbiological parameter on this occasion. The ward man hours recorded may be considered low and perhaps a different relationship may have been demonstrable on a busier ward.

Considering effect of external intake air microbiological quality, out data for Total Viable Count and those obtained for the levels of Gram +ve and Gram –ve contamination are given in table 2. All categories of count are significantly greater at the 95 % probability level than those obtained in ward irrespective of whether or not the UVc device was operating.

Correlation exists between the frequency of isolation , ratios and type of genera present in external air samples and those taken in the ward (tables 3 4 5 6 Graphs 7 8 9 10). This data strongly suggests that the composition of and relative frequencies of airborne organisms in this ward were a function of the microbiological composition of the intake air.

Further the external microbiological counts obtained for all categories of organism during period B are significantly higher than period B (Graph 5 & Graph 6). This factor does not seem to have

impacted significantly on the efficiency of the Medixair device because even though external air quality has been shown to be worse during period B our data demonstrated a significant improvement in microbiological air quality in the ward during UVc treatments (Graphs 1,2,,)

In relation to this observation, however it is interesting to observe the plot (Graph 4) of Total Viable Counts over periods A and B against the same data for external air intake for the same periods. During period A there does appear to be some correspondence of the TVC trend between the intake loading and ward loading. During period B when the Medixair device was operating and significantly higher external inputs were measured the trend is altered in manner which shows no agreement.

Per force the efficiency of the of the Medixair device was measured over two periods (A and B). Period A (the negative UVc control) has been shown to have lower levels of microbiological input from external air intake than during period B. Even so significant reduction of microbial loading was shown in the ward during period B (UVc on) when the challenge from external air input was greater.

This primary field trial has shown the Medixair UVc air treatment device is capable of significantly reducing air borne aerobic Gram +ve and Gram –ve bacterial contamination, during continuous use of the Medixair UVc unit, in a high care ward.

It is notable that this effect was demonstrable higher in a situation input levels of airborne microbial contamination was trending upwards.

Conclusion

Our data is encouraging in that, over the two periods, it was demonstrated that there was a significant ***(59%)*** reduction in the bio-burden even when challenged from a higher external input load.

Included within the observed levels of organisms during Period A was the presence of Staphylococcus aureus. During the second period, Period B with the machine switched on no Staphylococcus aureus was detected.

Appendix A

MEDIXAIR

The economic and social effects of Hospital Acquired Infection (HAI) are well recognised nationally and internationally[1]. Continued emphasis on hygiene procedures, the discovery of new drugs, changes in decontamination methods, and the development of new chemical treatments have all contributed towards combatting its(their) spread.

In the area of air borne contamination, the development of new air sterilisation devices also has an important role to play in closing the remaining gaps in patient protection. A recent development, the *Medixair* device, using ultraviolet technology has been developed by Brandenburg (UK) Ltd. This has been successfully tested under strict and independent laboratory conditions and is now being field-tested in the UK hospital arena.

FIELD TRIAL – PROTOCOL

1. Objectives

- To demonstrate the ease of operation of the *Medixair* UVc Air Sterilisation device in a live, hospital environment

- To produce appropriate data as evidence to ascertain the device's effectiveness in reducing the presence of (potentially) lethal pathogens (and) or indicator organisms/contaminants in the air

2. Process

The effectiveness of air sterilisation using the *Medixair* UVc Air Sterilisation Device, in the sterilisation of three strains of Staphylococcus aureus (NCTC 11939; NCTC 11940; NCTC 11962) has already been demonstrated in independent laboratory trials.[2] A similar methodology is utilised to establish its effectiveness in a normal hospital environment.

3. Equipment required

- A number of *Medixair*UVc Air Sterilisation Devices, depending on the cubic capacity of the location selected within the identified trial location (NB. a single *Medixair* device will provide 24m^3 of sterilised air per hour.)

- 1 Cassala Air Sampler device, utilising 6 Agar plates for each reading

4. Calibration/testing of equipment

- The *Medixair*device(s) to be tested by Brandenburg (UK) Ltd to ensure proper functioning prior to and upon installation. This includes checks to ensure there is no leakage from the irradiation chamber

- Calibration of the Cassala Air Sampler to be undertaken by Microsearch Laboratories, according to its standard procedures 5 days prior to the commencement of the trial

5. Installation and set up of equipment

- The *Medixair* device(s) to be installed in the location(s) and at the time agreed by the client, either by a Brandenburg (UK) installer or by a resident engineer or both, as agreed. For the purposes of the trial, it is not necessary to attach the device to a wall. It can be secured either to a table or to a trolley, which is locked into place and not moved

- The Cassala Air Sampler is placed on site in a location which does not interfere with the client's working procedures or patient comfort. It is retained in that position until the end of the trial period.

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[1] Refer to Meers, Aycliffe et al, *Report on the national survey of infection in hospitals. **J. Hosp. Infect., 1981*** & DHSS/PHLS Working Group, Guidance on the control of infections in hospital, **1988**

[2] *Antimicrobial Performance of the medixair UVc Air Sterilisation Device in the Sterilisation of Three Strains of Staphylococcus*: D. O'Connor, Microsearch Laboratories Ltd, Halifax. March 2002

➢ Both items of equipment must be covered by the client's existing insurance policy at replacement value .

6. Operating procedure

➢ The *Medixair* unit(s) is/are fitted with a 3-conductor cord and plug, and operate(s) from the mains electrical supply. Extension cords are not to be used with the device(s).

➢ The Cassala Air Sampler [TO BE COMPLETED BY DES O'CONNOR]

7. Monitoring & control

➢ Both pieces of equipment to be monitored on site, by the appointed trial supervisor from Brandenburg, during the trial which will last (1) Two weeks (Scenario 1) or (2) Two days (Scenario 2)

➢ The *Medixair* device employs short-wave ultraviolet radiation at 253.7 nano-metres to provide its antimicrobial benefits. It is interlocked to prevent inadvertent exposure to ultraviolet radiation.

8. Scope of action

➢ Cleaning of the air in the selected environment is achieved by the continual passing of air through the *Medixair* device at the rate of 24m^3 of sterilised air per hour. Different levels of protection can be obtained by adjusting the number of units installed in a given space, e.g.

	Protection level		
	High	**Medium**	**Low**
Air change every	**3 hrs**	**12 hrs**	**24 hrs**
Area covered	**31m^2**	**125m^2**	**250m^2**

➢ In order to preserve the "live" nature of the trial no changes to regular hospital routines are required. (an outline of hospital routines for the selected area should be submitted in advance to highlight issues that might have an impact on the test i.e. Consultant Ward rounds, nurse visits, equipment maintenance checks etc.)

➢ Instances of room cleaning, including hoovering, dusting or "fogging" must be recorded - i.e. activity, date, time of day and duration - to set against any changes recorded in the data produced

9. Procedure - Scenario 1

➢ <u>Testing over two weeks</u>

➢ Use 1 or 2 *Medixair* devices and one Cassala Air Sampler

➢ Trial supervisor to operate the Cassala, change over the Agar plates, pack, store and despatch them the following day

➢ Day 1 - install calibrated Cassala Air Sampler, early in the morning

➢ Switch on Cassala for 2 - 3 minutes at 10.00am and again at 4pm, take air samples and change the Agar plates after each period

➢ Cover, label and pack the Agars after each period

➢ Store the packed Agars overnight in … [TO BE COMPLETED BY DES O'CONNOR]

➢ The Agars to be collected and transported mid-morning, by Microsearch Ltd, direct to their laboratories in Halifax for analysis and recording [DES] Critical pick ups to be managed on a daily basis to ensure Agars reach Microsearch Laboratories within agreed critical timescales.

- ➢ Repeat the above steps for Days 2 - 7
- ➢ Day 7, switch on the *Medixair* device immediately after 4.00pm and allow to operate permanently
- ➢ Day 8, switch on Cassala for 2 - 3 minutes at 10.00am, take air sample and change the Agar plates
- ➢ Switch on Cassala for 2 - 3 minutes at 2-hourly intervals after 10.00am, until 4pm, take air samples and change the Agar plates each time (total of 4 readings)
- ➢ Cover, label and pack the Agars after each period
- ➢ Store the packed Agars overnight at ambient *sealed in the sample bags provided*.
- ➢ The Agars to be collected and transported mid-morning each day, by Microsearch Ltd, direct to their laboratories in Halifax for analysis and recording. *Fresh Agar resources will be provided on a daily basis.*
- ➢ Days 9 - 14 inclusive - keep *Medixair* device running 24hrs per day and take two daily air samples - at 10.00am and 4.00pm - using the Cassala sampler.
- ➢ Repeat covering, labelling and packing procedures for each day and continue to store and have agars picked up each day following air sampling.
- ➢ The results are analysed and reported within 2 to 3 weeks of end of trial

10. Procedure - Scenario 2

- ➢ Testing over two days only
- ➢ Use 1 *Medixair* device and one Cassala Air Sampler
- ➢ Trial supervisor to operate the Cassala, change over the Agar plates, pack, store and despatch them the following day.
- ➢ Day 1 - install calibrated Cassala Air Sampler, early in the morning
- ➢ Switch on Cassala for 2 - 3 minutes at 2-hourly intervals after 10.00am, until 4pm, take air samples and change the Agar plates each time (total of 4 readings)
- ➢ Cover, label and pack the Agars after each period
- ➢ Store the packed Agars overnight in *sealed in the sample bags provided*.
- ➢ The Agars to be collected and transported mid-morning, by Microsearch Ltd, direct to their laboratories in Halifax for analysis and recording [DES]
- ➢ Day 2, switch on Cassala for 2 - 3 minutes at 10.00am , take air sample and change the Agar plates
- ➢ Switch on the *Medixair* device immediately afterwards and leave to run all day
- ➢ Switch on Cassala for 2 - 3 minutes at 2-hourly intervals after 10.00am, until 4pm, take air samples and change the Agar plates each time (total of 4 readings)
- ➢ Cover, label and pack the Agars after both periods
- ➢ Store the packed Agars overnight in *sealed in the sample bags provided*.
- ➢ The Agars to be collected and transported mid-morning both days (i.e. days 2 and 3), by Microsearch Ltd, direct to their laboratories in Halifax for analysis and recording [DES]

- ➢ The results are analysed and reported within 10 working days

11. Maintenance

- ➢ The trial supervisor will inspect equipment and agar supplies daily to ensure full working order is maintained

12. Safety precautions

- ➢ The *Medixair* device is interlocked to prevent inadvertent exposure to ultraviolet radiation.
- ➢ The *Medixair* device will be secured to a table or the top of a trolley and the wheels locked in place.
- ➢ The table or trolley will be parked against a back wall of the selected location, away from passage ways
- ➢ Similarly the Cassala machine will be placed on a secured table away from passage ways
- ➢ All electrical wiring will be secured away from passage ways
- ➢ No extension cords will be used with the device(s).

13. Packaging & Storage of items

All agars will be provided in a ready to use state and will be supplied in sealed bags. All agar plates will be clearly labelled and provided in sufficient quantities to take duplicate samples. Materials will also be provided to assure Petri dish lid security.

All items supplied by Microsearch will be provided in a sanitary state.

14. Collection & Transportation of items

A Microsearch representative will attend on each day of the trial at an agreed time to provide a courier service. Our representative will also provide adequate supplies for completion of the next sample regime. Our courier may be contacted by mobile and will carry sufficient resources to cover off the need to repeat any sampling short fall. The courier will co-ordinate with Brandenburg personnel at the trial site. Microsearch will remove all items of trial related debris from the site in safe manner.

The Microsearch courier will carry appropriate identification and should be provided with a letter of authority to expedite access to the trials site.

15. Receipt of items at Laboratory

At the laboratory all plates will be individually identified and will be registered into the LIMS system and thereafter incubated under the prescribed conditions of test. Each plate will have an individual identifier which designates agar type and date of sampling.

16. **Method of analysis**

All methods of analysis and related confirmatory regimes will be traceable to applicable current B.S. or ISO standards which are defined in the attached schedule of accreditation (Appendix A)

17. **Recording of data**

All Laboratory data will be logged into LIMS system. The original laboratory hand written record will be retained for security purposes.

All calculations will be conducted in a manner which complies with the formulae stated in the applicable B.S. or ISO standard. Data will be compiled in a bespoke project database.

18. Analysis and reporting of results

Data will be presented in two formats. Firstly a short form report will be issued detailing the data obtained and immediate conclusions. This report will be available within 3 days of the final experimental data becoming available.

A more formal and broader scientific report will be issued within two weeks of completing the experimental stage of project.

19. Key References

1. *Antimicrobial Performance of the Medixair UVc Air Sterilisation Device in the Sterilisation of Three Strains of Staphylococcus*: Microsearch Laboratories Ltd, Halifax. March 2002

2. Meers, PD., Aycliffe, GAJ., Emmerson, AM., Leigh, DA., Mayon-White, RT., Mackintosh, CA and Stronge, JL., *Report on the national survey of infection in hospitals. J. Hosp. Infect., 1981, 2, (Supplement).*

3. Department of Health and Social Security/Public Health Laboratory service Hospital Infection Working Group, *Guidance on the control of infections in hospitals, Hospital Infection Control, 1988*

4. Sterilisation, Disinfection and Cleaning of Medical Devices and Equipment: *Guidance on Decontamination from the Microbiology Advisory Committee to Department of Health,* Medical Devices Agency, 1993 - 2000

20. Workflow chart