Microbial Air Sampling Report

Conducted in Three General Hospitals Malaysia

Conducted by

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1 Air Quality – An Introduction

"Fresh air can be full of transient populations of microorganisms, but none actually live for very long. Most microbes die off in the outdoor air as a result of sunlight, temperature extremes, dehydration, oxygen and pollution. Spores and some environmental bacteria are, however, naturally more resistant and can occur outdoors in high concentrations.

However, the controlled climate of indoor environments favours the survival and transmission of pathogens capable of infecting human beings. These embrace bacteria, viruses and certain outdoor fungi.

Since people spend 93% of their time indoors, protection against microbial aerobiological contamination must be provided through an engineered control of the indoor environment."

Pennsylvania State University: Department of Aerobiology

Medixair™ -
Air Sterilisation Unit

2 The Need for Air Sterilisation

The history of public health has witnessed a massive amount of growth in the understanding and development of protective services; beginning at the start of twentieth century when we began to come to terms with high mortality rates from poor diets, risks from child birth and poor sanitation. In the later half of the century, antibiotics and advancements in clean air further brought about even more dramatic improvements to health. More recently, as the new century begins we are dealing robustly with airborne contamination – from smoking and hospital acquired infections.

Microorganisms are found commonly in the environment, living amongst living beings on earth. Most of them are harmless and are found naturally in our surroundings. Microorganisms have little threats in outdoor air because ultraviolet irradiation from sunlight will kill them. Our lifestyles, however, are providing a perfect breeding ground for these microorganisms because they thrive in artificially-lit and heated environments. Many of us spend 93% of our time amongst these microscopic germs - in open-plan offices, leisure spaces, homes and multiple forms of transport. Strains of microorganisms resistant to antibiotics, most notably MRSA, have compounded the problem.

Competing technologies such as HEPA filters create breeding sites for these microorganisms and more often than not, we are introducing more microorganisms back into the air than we have removed. Therefore, the world need something powerful enough to actually target and kill, not just remove, all the microorganisms that cause both mild and severe illnesses – ranging from the common cold and influenza to the myriad of more serious illnesses such as tuberculosis, measles, mumps and chickenpox.

Much of the spread of infection has been traditionally considered to be linked to droplet nuclei, spread by sufferers of respiratory diseases such as colds and flu. More stubborn hospital acquired infections caused by bacteria such as *Staphylococcus* sp. and other Gram positive bacteria may be attributable to dust and skin particles that are actually carrying bacteria and viruses around hospital wards and treatment areas.

Today influenza and hospital acquired infections continue to result annually in thousands of deaths, and many more suffer each year from poor health and illness contracted in the workplace.

An engineered solution, however, is now at hand. Medixair is a device that can actually kill microorganisms, not merely removing them from the air. Medixair uses ultraviolet irradiation, the UVC band to be specific, that is capable of disrupting bacteria and viral DNA, thus preventing reproduction. Crucially, the device addresses the fact that ultraviolet light does not propagate very far through air and loses 75% of its energy once it is more than 2 inches away from its source. Medixair utilises the power of ultraviolet light in an innovative way to ensure that all microorganisms entering the Medixair will be exposed to a sufficient level of radiation to render them totally harmless in a single pass.

Please refer to the appendix for an indication between the energy required to kill microorganisms and the energy produced by Medixair. The information showed that all known bacteria and viruses, and many fungi are effectively killed by Medixair.

Medixair has recently been the subject of a full clinical trial in a 900 bed acute hospital where it has demonstrated statistically significant improvements in the levels of airborne pathogens. This resulted in a consequential reduction in patient colonisation and infections. The results of the trial have been described by the clinical staff as outstanding and the have now been published at the 8th International Congress of the International Federation of Infection Control in Budapest, Hungary.

3 Microbial Air Sampling

General Hospitals

This report describes the microbial air sampling carried out at the above premises between the period of 27 August 2007 and 05 October 2007.

3.1 Objective

The objective of this study was to evaluate and assess the air quality in particular to specific microbial activity before and after installation of Medixair at the selected locations.

3.2 Air Sampling Locations

The microbial air samplings were carried out at the following locations:

1) Hospital Kuala Lumpur, Wilayah Persekutuan

a) Burn Care Ward 3, Level 2, Main Block
   i) Room 2
   ii) Room 3
   iii) Bilik Rehabilitasi
b) CCU, Level 4, Main Block
   i) Cubicle 5
   ii) Cubicle 6

2) Hospital Tengku Ampuan Rahimah, Klang, Selangor

a) Burn Care Ward, Room 1, Level 3
b) ICU, Isolation Room 2, Level 5
c) Ward 6A, Isolation Room 4, Level 6

3) Hospital Pulau Pinang, Pulau Pinang

a) CCU Room 1
b) CCU Room 6
c) CICU Bed 7 (Room)

4) Hospital Seberang Jaya, Pulau Pinang

a) ICU A, Isolation Room
b) CCU
c) HDU

5) Hospital Sultanah Aminah, Johor Bahru, Johor

a) CICU, Isolation Room, Level 1
b) ICU Utara, Isolation Room 7, Level 2
c) NHDU, Isolation Room, Level 4

Total Viable Count (TVC) in CFU/m^3 was sampled during the course of this study.

3.3 Methodology

The microbial air sampling was carried out using a portable microbiological air sampler BIOTEST RCS Hi Flow to collect indoor air samples for microbial activity. Total Count Agar was used as a sampling medium for Total Viable Count with a two minutes sampling period (200 litres of air) and was then incubated for 72 hours at 30^{o}C prior to microbial counts.

All the agar samples were submitted to Spectrum Laboratories (M) Sdn. Bhd. for incubation and enumeration. At the end of incubation, the number of visible bacteria represented as colony forming units (CFU), was counted and this number was related to the volume of air sampled. Results were then normalised to give CFU/m^3.

The results reported included in this documentation are contained in the analysis certificate issued from Spectrum Laboratories (M) Sdn. Bhd.

3.4 Records of Field Activities

During the course of this study, the following activities were recorded:

A. Hospital Kuala Lumpur

One (1) patient was admitted in the Burn Care Ward Room 2, CCU Cubicle 5 and CCU Cubicle 6, whereas, Burn Care Ward Room 3 And Bilik Rehaibilitasi were vacant during the course of this study. All the rooms and cubicles were air-conditioned except Bilik Rehabilitasi, which was slightly warm and stuffy.

S/No.	Locations	Activities recorded	
		27 August 07 & 03 September 07 (Without Medixair)	**07 September 07 & 01 October 07 (With Medixair)**
1.	Burn Care Ward Room 2	27 August 2007 Minimal movement in room	07 September 2007 Two (2) nurses were changing dressings for patient **during** the course of sampling 01 October 2007 Nurses were changing dressings for patient. Waited for **10 minutes after the dressing changing** procedure was completed before carrying out sampling Cleaners went into the room immediately before sampling was performed, left the room without performing any cleaning Room was messy and the rubbish bins were full

2.	Burn Care Ward Room 3	No activities recorded prior to sampling	No activities recorded prior to sampling
3.	Burn Care Ward Bilik Rehabilitasi	One (1) nurse was in the room prior to sampling	No activities recorded prior to sampling
4.	CCU Cubicle 5	Nurses and doctors were performing medical check-ups for patient	No activities recorded prior to sampling One (1) nurse monitored patient from the desk located outside the cubicle
5.	CCU Cubicle 6	Patient was pushed out of the cubicle (including bed) to undergo treatment at other location Cleaner was dusting and cleaning the room immediately after patient was pushed out and prior to sampling	No activities recorded prior to sampling Nurse informed us that the patient in this cubicle had MRSA infection

B. Hospital Tengku Ampuan Rahimah

One (1) patient was admitted in all rooms in which sampling was performed during the course of this study.

S/No.	Locations	Activities Recorded	
		04 September 2007 (Without Medixair)	**07 September 07 (With Medixair)**
1.	Burn Ward Room 1	One (1) visitor was attending to the needs of the patient Door to the room was opened Patient got up from bed and went out of the room during the course of sampling	Patient admitted in the room was the same as on 04 September 2007 One (1) visitor was attending to the needs of the patient Visitor helped to elevate the bed of the patient during the course of sampling
2.	ICU Isolation Room 2	No activities recorded prior to sampling	No activities recorded prior to sampling
3.	Ward 6A Isolation Room 4	Three (3) nurses and one (1) doctor were performing medical procedures Door partially opened	One (1) nurse was attending to the patient Medixair was found to be switched off. It was immediately switched on and left to run for between 30 and 45 minutes before samples were taken. Door was closed during this period

C. Hospital Pulau Pinang

One (1) patient was admitted in all rooms on 10 September 2007, whereas, CICU Bed 7 (Room) was vacant during the course of this study. CCU Room 1 was also empty on 14 September 2007. All the rooms were air-conditioned.

S/No.	Locations	Activities Recorded	
		10 September 2007 (Without Medixair)	**14 September 07 (With Medixair)**
1.	CCU Room 1	Nurses were going in and out of room and were performing medical procedures/check-ups Curtain to the room was opened and closed repeatedly	Room was empty Curtain was closed
2.	CCU Room 6	No activities recorded prior to sampling Curtain was opened	Curtain was drawn closed Staff performing suction procedures
3.	CICU Bed 7 (Room)	Doors opened Room crowded with machines	Door partially opened Room crowded with machines

D. Hospital Seberang Jaya

One (1) patient was admitted in ICU A while three (3) patients each were admitted in CCU and HDU during the course of this study.

S/No.	Locations	Activities Recorded	
		10 September 2007 (Without Medixair)	**14 September 07 (With Medixair)**
1.	ICU A Isolation Room	Door was opened One (1) doctor and two (2) nurses were attending to the patient	Door was opened Patient admitted in the room was the same as on 10 September 2007 Two (2) nurses were attending to the patient
2.	CCU	Four-bedded room Two (2) nurses went in and out of the room	Four-bedded room One (1) nurse was in the room while another nurse walked into the room half way during sampling
3.	HDU	Four-bedded room One (1) nurse walked in and out of the room One (1) doctor was performing medical check up for one (1) of the patients in the room	Four-bedded room One (1) of the Medixair units was found switched off prior to sampling. The unit was immediately switched on and sampling performed Two (2) nurses in the room

E. Hospital Sultanah Aminah

One (1) patient was admitted in ICU Utara Room 7 while CICU Isolation Room was vacant during the course of this study. NHDU Isolation Room had two (2) patients admitted on 3 October 2007 and four (4) patients on 5 October 2007. All rooms except NHDU was air conditioned.

S/No.	Locations	Activities Recorded	
		03 October 2007 (Without Medixair)	**05 October 07 (With Medixair)**
1.	ICU Utara Room 7	One (1) nurse walked in and out of the room to attend to the patient Door was slightly opened A group of doctors and nurses were outside the room The patient admitted in the room was an immuno-compromised patient	One (1) nurse was attending to the patient Door wide opened
2.	CICU	Door was opened Water leaking from air conditioner and ceiling	Door was closed Water leaking from air conditioner and ceiling
3.	NHDU	Four-bedded room with only two (2) beds occupied Warm with fan Door opened	Four-bedded room with all four (4) beds occupied Warm with fan Door closed

		Nurses went in and out of the room	Two (2) nurses performing suction procedures on one (1) of the patients One (1) doctor and two (2) nurses were attending to the other patients

4 Results

All the respective test results obtained are tabulated below:

Table 1: Total Viable Counts (TVC) in Hospital Kuala Lumpur on 27 August 2007, 03 and 07 September 2007 and 01 October 2007

S/No	Locations	27 Aug 07 Without Medixair	03 Sep 07 Without Medixair	07 Sep 07 With Medixair	01 Oct 07 With Medixair	Total Percentage Reduction
		TVC CFU/m^3	TVC CFU/m^3	TVC CFU/m^3	TVC CFU/m^3	%
1.	Burn Care Room 2	235	NA	495	30	**87.2**
2.	Burn Care Room 3	35	NA	30	NA	**14.3**
3.	Burn Care Bilik Rehabilitasi	245	NA	140	NA	**42.9**
4.	CCU Cubicle 5	*NA	910	100	NA	**89.0**
5.	CCU Cubicle 6	NA	735	325	NA	**55.8**

*NA refers to Not Applicable

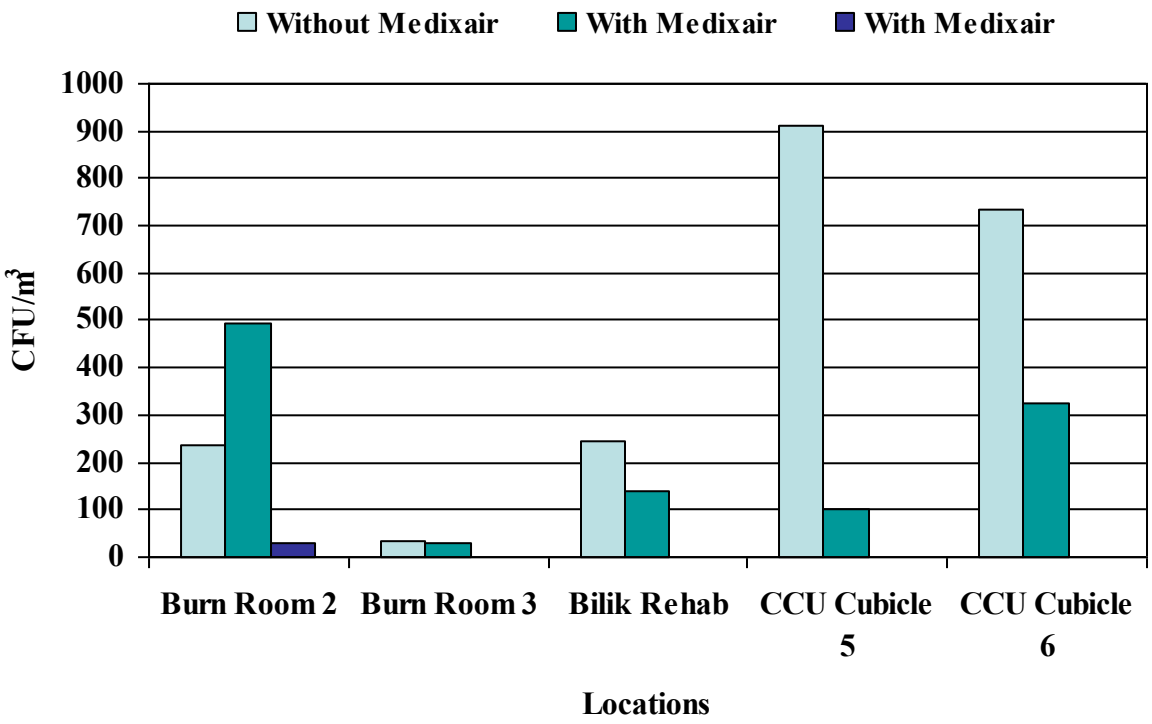

Figure 1: Total Viable Counts (TVC) in Hospital Kuala Lumpur on 27 August 2007, 03 and 07 September 2007 and 01 October 2007

Table 2: Total Viable Counts (TVC) in Hospital Tengku Ampuan Rahimah on 04 and 07 September 2007

S/No	Locations	04 Sep 07 Without Medixair	07 Sep 07 With Medixair	Total Percentage Reduction
		TVC CFU/m^3	TVC CFU/m^3	%
1.	Burn Ward Room 1	395	85	**78.5**
2.	ICU Isolation Room 2	140	40	**71.4**
3.	Ward 6A Isolation Room 4	325	100	**69.2**

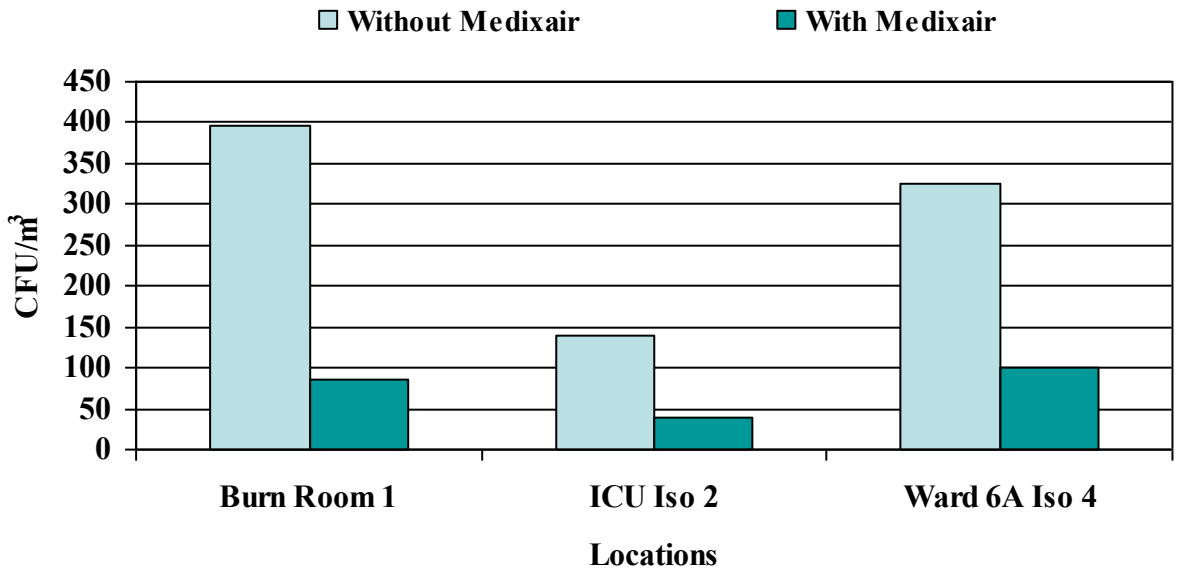

Figure 2: Total Viable Counts (TVC) in Hospital Tengku Ampuan Rahimah on 04 and 07 September 2007

Table 3: Total Viable Counts (TVC) in Hospital Pulau Pinang on 10 and 14 September 2007

S/No	Locations	10 Sep 07 Without Medixair	14 Sep 07 With Medixair	Total Percentage Reduction
		TVC CFU/m^3	TVC CFU/m^3	%
1.	CCU Room 1	220	75	**65.9**
2.	CCU Room 6	175	160	**8.6**
3.	CICU Bed 7 (Room)	180	10	**94.4**

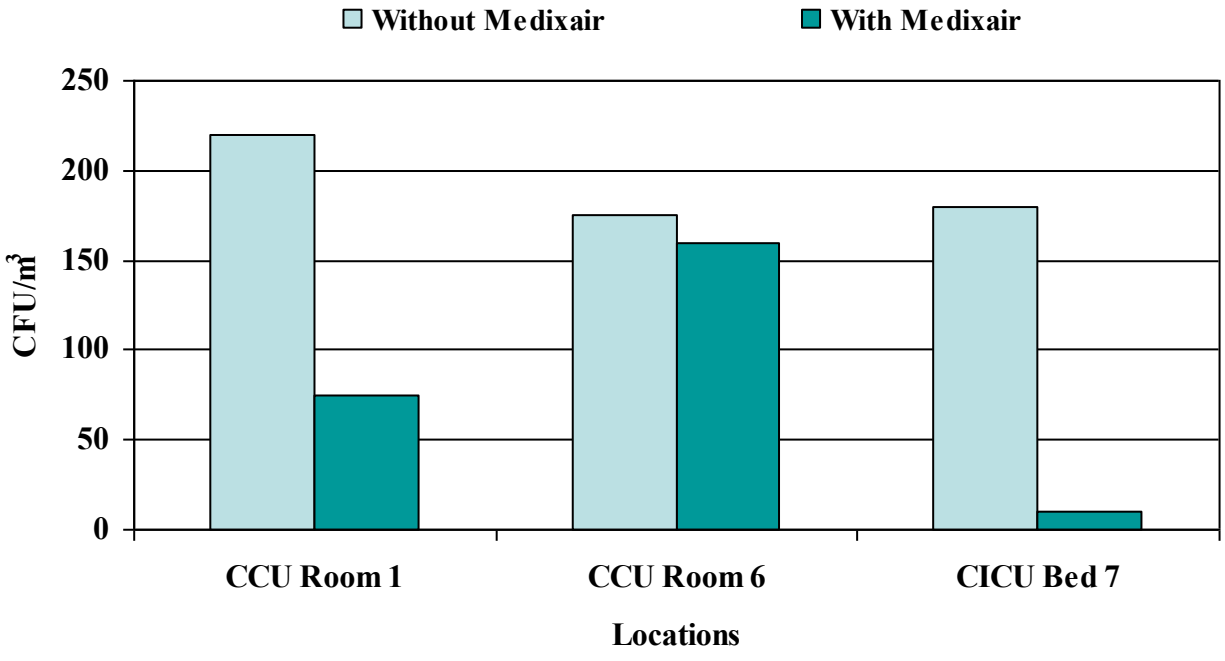

Figure 3: Total Viable Counts (TVC) in Hospital Pulau Pinang on 10 and 14 September 2007

Table 4: Total Viable Counts (TVC) in Hospital Seberang Jaya on 10 and 14 September 2007

S/No	Locations	10 Sep 07 Without Medixair	14 Sep 07 With Medixair	Total Percentage Reduction
		TVC CFU/m^3	TVC CFU/m^3	%
1.	ICU A Isolation Room	990	250	**74.7**
2.	CCU	620	440	**29.0**
3.	HDU	*TNTC	250	**> 80%**

*TNTC refers to Too Numerous to Count

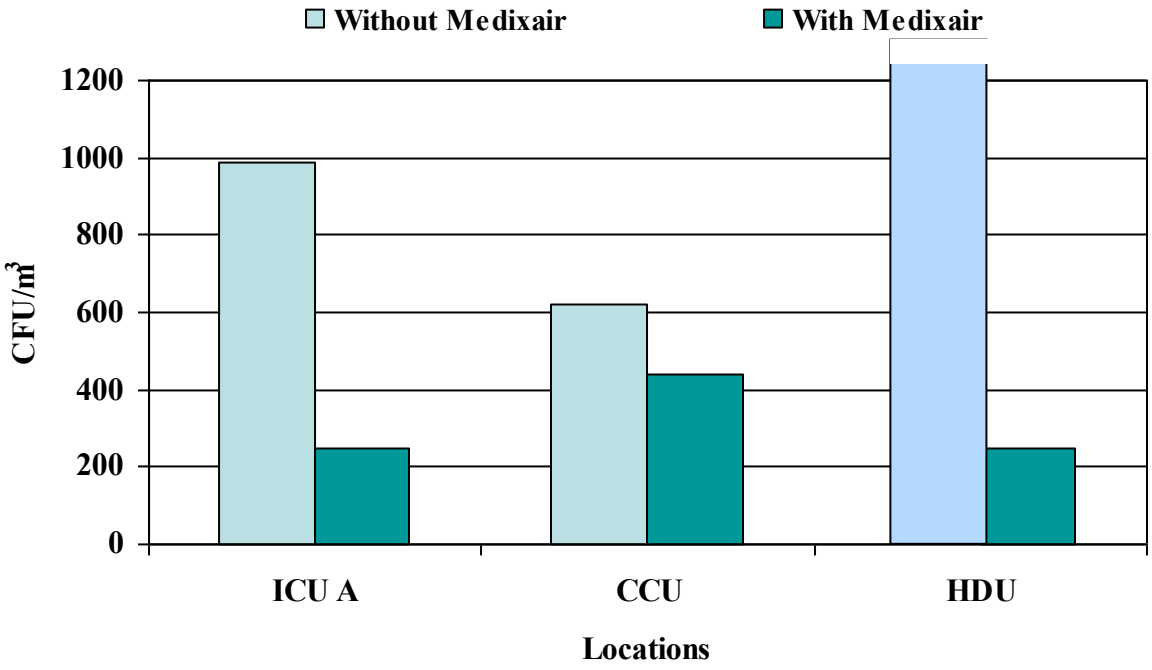

Figure 4: Total Viable Counts (TVC) in Hospital Seberang Jaya on 10 and 14 September 2007

Table 5: Total Viable Counts (TVC) in Hospital Sultanah Aminah on 03 and 05 October 2007

S/No	Locations	03 Oct 07 Without Medixair	05 Oct 07 With Medixair	Total Percentage Reduction
		TVC CFU/m^3	TVC CFU/m^3	%
1.	ICU Utara Room 7	340	165	**51.5**
2.	CICU Isolation Room	145	5	**96.6**
3.	NHDU Isolation Room	385	130	**66.2**

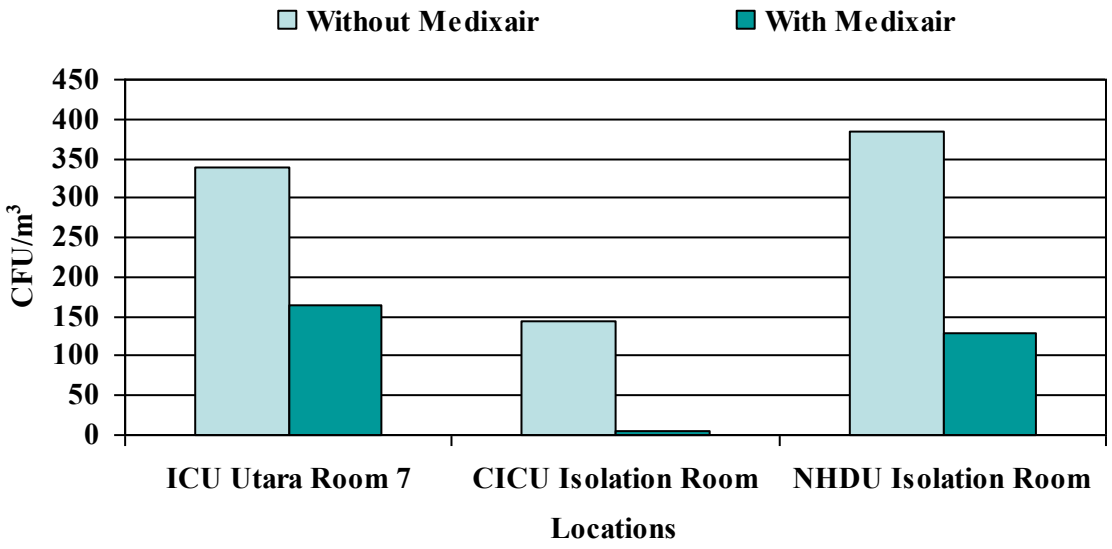

Figure 5: Total Viable Counts in Hospital Sultanah Aminah on 03 and 05 October 2007

5 Discussion

The microbial air samplings were carried out in the period between 27 August 2007 and 05 October 2007.

5.1 Hospital Kuala Lumpur

The results showed that the initial total viable counts in the rooms in the Burn Care Ward were between 35 and 245 CFU/m^3. Relatively high total viable counts that ranged between 735 and 910 CFU/m^3 were recorded in the cubicles sampled in CCU on 03 September 2007. After Medixair was installed, marked reductions in total viable counts that ranged from 14.3% to 89.0% were recorded on 07 September 2007 except for Burn Care Ward Room 2, which recorded an increase.

Localised increase of contamination with bacteria was likely associated with dressing changing and cleaning up of body and wounds of the patient in this particular room while air samples were being collected. The removal of dressings was likely to have contributed to the dissemination of aerosol particles from the contaminated wounds of the patient to the environment, leading to an increased reading.

In view of this increase, another air sampling was carried out in the same room on 01 October 2007. Another dressing changing procedure took place when we arrived to carry out the air sampling. This time we allowed 10 minutes after completion of the procedure before carrying out the air sampling to allow time for Medixair to sterilise the air that had been contaminated by bacteria from the patient's body, wounds and dressings. Indeed Medixair gave a recorded total viable count of 30 CFU/m^3, resulting in a total reduction of 87.2% on 01 October 2007 compared to 27 August 2007.

5.2 Hospital Tengku Ampuan Rahimah

Generally, the total reductions recorded for this hospital were quite consistent, with reductions that ranged between 69.2% and 78.5%. Before Medixair units were installed, the total viable counts were recorded in the range of 140 and 395 CFU/m^3 but reduced to 100 CFU/m^3 and below after the installation of Medixair.

It should be highlighted that the Medixair units were switched off in Ward 6A Isolation Room 4 before the post-test air sampling was conducted. In order to carry out the air sampling, the door to the room was closed and the units were allowed to operate for 30 to 45 minutes instead of 36 hours before air sampling were carried out. Even though Medixair was only allowed to run for a short period of time, a reduction in total viable counts of up to 69.2% was recorded, thus clearly showed the capability and effectiveness of Medixair in the clinical settings.

5.3 Hospital Pulau Pinang

The results showed that the total viable counts in CCU and CICU ranged between 175 and 220 CFU/m^3 before Medixair units were installed. After installation of Medixair units, reductions that ranged from 8.6% to 94.4% were recorded on 14 September 2007.

The percentage reduction in CCU Room 6 was lower (less than 10%) compared to other locations in this hospital due to suction activities that were taking place in this room during the course of sampling. Suction activities could have caused a dissemination of microorganisms into the air, leading to a higher level of bacteria detected in the samples.

5.4 Hospital Seberang Jaya

Based on the results obtained, the total viable counts recorded on 10 September 2007 (before Medixair installation) were 990 CFU/m^3, 620 CFU/m^3 and Too Numerous to Count, for ICU A, CCU and HDU, respectively. After Medixair units were installed in these locations, reductions of 74.7% and 29% were observed in ICU A and CCU, respectively, whereas a reduction of more than 80% was observed in HDU.

There were four (4) units of Medixair allocated to CCU but upon arrival to the location and prior to air sampling, it was found that one of the units was switched off. The unit was immediately switched on and then air sampling carried out. This could have contributed to the lower reduction percentage in CCU as compared to ICU A and HDU since the speed of Medixair's effectiveness is based upon the size of a particular room. In other words, it would take a shorter time for four units of Medixair to sterilise the space in CCU compared to only three units.

5.5 Hospital Sultanah Aminah

The results recorded for total viable counts in ICU Utara Room 7, CICU Isolation Room and NHDU Isolation Room in this hospital were 340, 145 and 385 CFU/m^3, respectively before Medixair were installed. After Medixair were installed, the total viable counts showed marked reductions that ranged from 51.5% to 96.6%.

6 Conclusion and Recommendation

This report showed that Medixair effectively helped to control and reduce the microbiological contamination in the rooms tested based on the following results obtained:

1) Hospital Kuala Lumpur - An **average total reduction of 57.8%** in total viable count was observed with the **highest reduction of up to 89%** recorded in CCU Cubicle 5 on 07 September 2007 compared to 03 September 2007
2) Hospital Tengku Ampuan Rahimah - An **average total reduction of 73%** in total viable counts was observed with the **highest reduction of up to 78.5%** recorded in Burn Ward Room 1 on 07 September 2007 compared to 04 September 2007
3) Hospital Pulau Pinang - An **average total reduction of 56.3%** in total viable count was observed with the **highest reduction of up to 94.4%** recorded in CICU Bed 7 (Room) on 14 September 2007 compared to 10 September 2007
4) Hospital Seberang Jaya - An **average total reduction of 61.2%** in total viable count was observed with the **highest reduction of more than 80%** recorded in HDU on 14 September 2007 compared to 10 September 2007
5) Hospital Sultanah Aminah - An **average total reduction of 71.4%** in total viable count was observed with the **highest reduction of up to 96.6%** recorded in CICU Isolation Room on 05 October compared to 03 October 2007

In general, due to uncontrolled environment and dynamic human activities such as routine medical surveillance by doctors and staff nurses, visitors' movements, disturbed air condition caused by opening of windows and doors, some of the results obtained showed a lower percentage of reduction, or an increase in the case of the Burn Care Ward Room 2 on 07 September 2007 due to dressing changing procedures. Nevertheless, the overall performance of Medixair can be regarded as excellent and has proven to be effective to control and achieve a high reduction of microbial activities of up to 63% in the clinical environment.

Preventative maintenance is probably the single most important strategy for maintaining and controlling good air quality within the clinical environment. It is recommended that

all general hospitals in Malaysia install Medixair in the crucial clinical environment in particular in the intensive care units as well as isolation rooms. This is aimed to achieve an effective control of microbiological contaminants from entering the critical medical environment as well as to provide a total protection to the patients and staff from any airborne pathogenic infection within the hospital environment. The hospital may also use this information to further establish the importance of effective control measures for good indoor air quality to meet the highest hospital cleanliness standards.

Based on the air sampling results obtained, we are confident that Medixair will improve the air quality in the clinical environment and achieve higher cleanliness standards in relation to the hospital's medical facilities. It will then minimise any possible outbreak of pathogenic infections such as MRSA, pseudomonas and other nosocomial infections as well as in achieving higher treatment productivity and medical standards.

Medixair is safe for use in the hospital environment and should be allowed to run continuously i.e. 24 hours and not switched off at night, for the unit to achieve its maximum capability in providing the highest level of protection.

It should be noted that this study is based upon relevant information gathered during the execution of this project and reflects our findings at the date/time and locations sampled.

Reported by:

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Appendix A

Medixair = **22,500** µWs.cm^{-2}

Bacteria	µWs.cm^{-2}
Agrobacterium tumefaciens	8,500
Bacillus anthracis	8,700
Bacillus megaterium (spore)	5,200
Bacillus megaterium	2,500
Bacillus subtilis (spore)	22,000
Bacillus subtilis	11,000
Bacillus paratyphosus	6,100
Bacillus enteritidis	4,000
Corynebacterium diphteriae	6,500
Clostridium tetani	23,100
Clostridium botulinium	11,200
Dysentry bacilli	4,200
Eberthella typhosa	4,100
E.coli	8,600
Leptospira spp (Infectious jaundice)	6,000
Legionella pneumophila	2,760
Legionella bozemanii	3,500
Legionella dumoffii	5,500
Legionella gormanii	4,900
Legionella micdadei	3,100
Legionella longbeachae	2,950
Listeria monocytogenes	3,400
Micrococus candidus	12,300
Micrococus sphaeroides	15,400

Bacteria	µWs.cm^{-2}
Mycobacterium tuberculosis	10,000
Neisseria catarrhalis	8,500
Phytomonas tumefaciens	10,500
Proteus vulgaris	3,900
Pseudomonas aeruginosa	6,600
Pseudomonas fluorescens	7,600
Salmonella enteritidis	10,000
Salmonella paratyphi	15,200
Salmonella typhimurium	10,500
Salmonella typhosa	6,000
Sarcina lutea	4,200
Serratia marcesens	3,400
Shigella dysenteriae	3,400
Shigella paradysenterea	8,500
Shigella flexneri	7,000
Shigella sonnei	6,600
Spirillium rubsum	4,400
Staphylococcus albus	5,720
Staphylococcus aureus	6,600
Streptococcus haemolyticus (A)	5,500
Streptococcus haemolyticus (D)	9,500
Streptococcus lactis	8,850
Streptococcus viridans	3,800
Streptococcus pyrogenes	4,200
Streptococcus salivarius	4,200

Viruses	µWs.cm^{-2}
Adenovirus 3	4,500
Bacteriophage (E.coli virus)	6,600
Coxsackievirus A9	12,000
Coxsackievirus B1	15,500
Echovirus 1	11,000
Echovirus 2	12,000
Hepatitis A	11,000
Infectious hepatitis virus	8,000
Influenza	3,400
Poliovirus (poliomyelitis)	6,500
Poliovirus 1	21,000
Poliovirus 2	12,000
Poliovirus 3	10,000
Reovirus 1	15,400
Rotavirus SA11	24,000
Variola virus	23,000

Yeasts	µWs.cm^{-2}
Saccharomyces cerevisiae	6,000
Saccharomyces ellipsoids	6,000
Brewer's yeast	3,300
Baker's yeast	3,900

Mould Spores	µWs.cm^{-2}
Aspergillus flavus	99,000
Aspergillus glaucus	88,000
Aspergillus niger	100,000
Mucor racemosus a/b	35,200
Oospora lactis	11,000
Penicillium digitatum	88,000
Penicillium expansum	22,000
Penicillium roqueforti	26,400
Rhizopus nigricans	220,000

Appendix B