Technical Discussion of Medixair

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Technical discussion of Medixair

Medixair utilises ultraviolet light at a specific wavelength of 253.7 nanometres. At this wavelength ultraviolet light is germicidal. In order to provide successful intervention in the airborne transmission of pathogens we need to process the air within the room at a rate greater than the rate of challenge from the source

As every environment presents a different set of conditions it is impossible to predict every eventuality or potential outcome. As such we should design our device to provide as much processing capacity as possible. However, constraints such as cost, physical size, noise, and convenience of installation also need to be recognised.

The key parameters that affect product design performance are

1) Kill energy of the target organisms
2) Irradiance properties UV
3) Air flow within the space to be decontaminated

Kill energy of the target organisms

As researchers have identified, to provide an effective kill rate the microorganisms must be irradiated with sufficient energy to achieve effective sterilisation. The percentage pathogen kill rate can be determined from by using equation 1[3]:

$$\frac{C_t}{C_0} = e^{-kEt} \qquad (1)$$

where:
- k = UV susceptibility constant for pathogen (m^2/J)
- C_t = Contaminant concentration at time t (cfu/m^3)
- C_o = Contaminant concentration at t = 0 s (cfu/m^3)
- E = UV irradiance
- t = Duration of exposure to irradiation

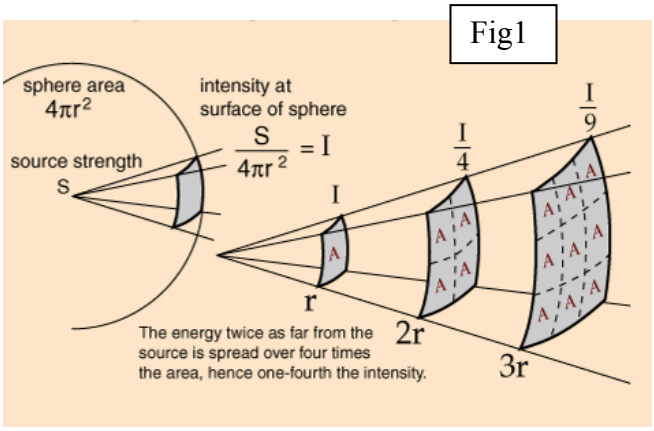
The energy required to kill a wide range microorganic species have been identified. Therefore to produce effective air decontamination device the kill energy of the device must be defined.

Whilst within the literature much has been done to identify the susceptibility of given pathogens. Medixair has been specifically tested in the laboratory to actually verify its effectiveness against key organisms [4,5,6]

Irradiance properties of ultraviolet

The lack propagation of UV through air must also be considered. In design terms we begin by defining power. For convenience this is measured as irradiance, this being defined as the power of UV at a unit area of surface. The (SI) unit for irradiance is Watts per square metre ($W \cdot m^{-2}$).

Fig1



If a point source radiates light uniformly in all directions, then the irradiance decreases in proportion to the distance from the object squared, since the total power is constant and it is spread over an area that increases with the square of the

distance from the source (the inverse square law). Fig 1

Researchers have applied themselves extensively to the modelling of UV sources, and the problem of defining the irradiation of a spherical body (microorganism). The problems of photo-sensing and data interpretation can be avoided through analytical determination of the 3D intensity field. The use of radiation view factors to define the 3D intensity field for both the lamp and internal reflective surfaces has been detailed by Kowalski and Bahnfleth (2000).[3]

Based on this approach manufacturer's data has generated data to describe the rate of decay of UV through air. This data suggests that at a distance of 5cm, 75% of the irradiance is lost. This makes the need to bring the target organism as close as possible to the source of vital importance. To illustrate this point a three dimensional plot of this loss of irradiance is shown in figure 2. The dramatic loss of irradiance makes it problematic to provide a useful level of power within a given space.

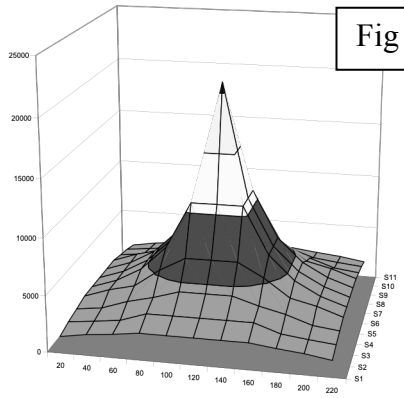


Fig 2

The Medixair device employs a chamber into which UV light sources are placed longitudinally i.e. parallel to the airflow By arranging the UV sources in an array it is possible to provide a complimentary reinforcement of one source from another.

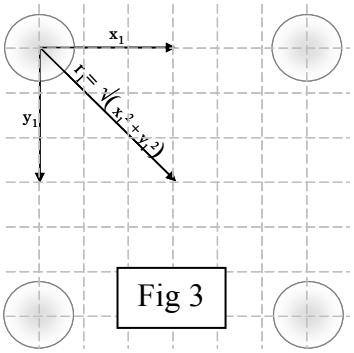


Fig 3

Examination of the chamber in cross section enables the definition of irradiance at each point across the surface. This is done for each source in turn, and then summing the result for the total number of sources- four in the case of Medixair.

For each point this is done by defining grid of x and y coordinates and calculating the Pythagorean distance for each point from each source in the array. Fig3

With the use of a lookup table derived from manufacturers data of irradiance vs distance based on the inverse square relationship we can calculate the irradiance for any given point in the cross section which can then be summed for each source

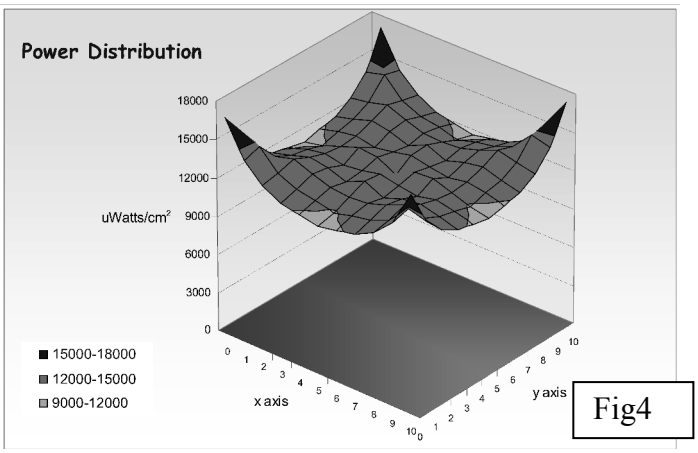


Fig4

A typical four tube array will produce a plot as shown in figure 4. This arrangement will provide a much higher and therefore more useful amount of available power.

Additional irradiance can further be achieved by choice of materials for the chamber enclosure. *Kowalski et al* [5] have defined levels of reflectivity for internal surfaces and whilst high levels of

reflection can be achieved (upto 90%) choice of commercially available and cost effective materials must also be considered. Use of aluminium with a suitable surface treatment will deliver and internal reflection of >70%.

Exposure Time
The next parameter to consider is the time spent by a microorganism in the power field. To maximise the exposure the organism should be made to travel as slowly as possible commensurate with providing enough airflow to deliver a satisfactory volume of air. Much consideration is given to whether the air flow is laminar or turbulent. Inevitably turbulence and mixing of the air will take place and as such will be advantageous to time spent in the chamber. However by treating the flow as laminar we are designing for worst case. Given the area of the chamber and the desired volume flow rate we can derive the air speed through the chamber. This air speed when multiplied by minimum irradiance will provide the kill energy.

The air flow through the machine is maintained at a relatively, low speed ($0.3m.s^{-1}$) which exposes bacteria to the powerful radiation field within the machine. The combination of irradiance power measured in $\mu W.cm^{-2}$ and time in seconds provides a useful amount of energy ($22{,}500\mu W.sec.cm^{-2}$) capable of providing logarithmic reductions of microorganisms

Design Parameters.
Selection of key parameters becomes a matter of critical judgement to define a device that will be effective. The following points have to be considered.

1) Provision of adequate energy to kill the maximum number of pathogens.
   Virus and bacterial pathogens which create a number of heath care associated infections (HCAI) are the priority. Certain fungal spores e.g. *Aspergillius spp* would require massive kill energy that would make the device too large for practical application

2) Produce sufficient airflow to enable the adequate servicing of a room.
   A well ventilated space reduces the risk of HCAI. The application of a portable device enables the installation of UV within an existing ward which may otherwise be poorly ventilated. Degrees of decontamination can be increased by increasing the number of devices.

3) To make the air speed commensurate with an acceptable level of noise.
   High air speed will make a fan driven device unacceptably intrusive for the patient. Whilst noise damping can be applied it is the volume of air being moved that is the most critical parameter with respect to noise.

Many earlier devices did not protect the observer from exposure to the UV. Ultraviolet, at this germicidal wavelength, has a minimum exposure value that makes it necessary to take special precautions to prevent photokeratitis and photoconjunctivitis (inflammation of the cornea and the conjunctiva, respectively).[1] As Medixair is completely encapsulated both patients and healthcare workers can work safely whilst the machine is operating.

Further by restricting the emission of ozone forming wavelengths between 160nm to 220nm Medixair is capable of being placed within close proximity to patients and within confined spaces without detrimental effects.

Therefore the design of Medixair has overcome the safety issue without compromising its killing effect against microorganisms. The design allows Medixair to deliver UV-c

light in a safe but highly effective way as the tubes are encased and no UV light escapes the unit.

Additionally to determine the ability of Medixair to sterilise a given space, computational fluid dynamic modelling (flow-solver CFX-5) was employed which defined the thermally driven flow properties for air being processed and to predict the outcome. The physical characteristic, of the numerical model, included turbulence in the environment, which was important for mixing near the Medixair outlet. The buoyant effect of the exit air was included. Once the flow solution had been obtained, streamlines were calculated to show the path of particles carried by the airflow. This process demonstrated that the decontaminated air leaving the machine was capable of mixing with the ambient air diluting the level of contamination with time.[7]

Core Technological Features of Medixair

A fundamental property of UV light is that it does not propagate well through the air. As can be seen from the below chart at 5cms or (2ins) from the UV light source 75% of the power has been lost.

To overcome this problem Medixair units comprise 4 tubes built into an array. This allows each tube to reinforce the power from its neighbour. In this way we have been able to construct a power distribution of sufficient intensity to provide the basis for a UVGI – Ultra Violet Germicidal Irradiation – machine.

During development we measured a variety of different materials in order to select an ideal candidate for inclusion as an internal reflector. Through the incorporation of this material in tandem with the multi-lamp array we have been able to produce a very dense and intense power field.

The next stage of product development was to review ways and means to optimise the exposure time of air passing through the unit to the power field.

In this context our research had indicated that many competitive products seek to produce high rates of air flow – seeking to effect a cycle of rapid air change within target room spaces.

Medixair has been constructed on the basis that the purpose of the machine is to destroy airborne micro-organisms within a single pass through the irradiation chamber. This we achieve through controlling the speed of the air during its journey through the Medixair unit. In other words we take the approach that it is better to provide a controlled and wholly appropriate air speed to support the purpose of the machine – rather than to blow air ineffectively at great speed through and past the light source. This approach has now been proven to be effective by virtue of a number of actual case studies (sic).

The level of energy required to kill a variety of micro-organisms is described in the below table. As can be observed, Medixair is capable of eliminating all bacteria and viruses. It will however be noted that certain moulds - e.g. Aspergillus Niger - are especially resilient. At the time of writing a research programme is underway to identify a methodology for eliminating these types of moulds within the current Medixair technology.

In general the range of organisms susceptible to Medixair is such that we can predict a very much improved air quality with attendant benefit in infections.

Energy	=	Power X Time	
Minimum power irradiation from a single tube at 5cm	=	3,750	$\mu W.cm^{-2}$
Power Irradiation from 4 tubes	=	15,000	$\mu W.cm^{-2}$
Expose time at 0.3m/sec	=	1.5	secs
	=	22,500	$\mu W.secs.cm^{-2}$

Kill Energies

Note: Medixair = 22,500 $\mu W.s.cm^{-2}$

Virus	Energy
Adenovirus 3	1,500
Bacteriophage (E. Coli virus)	3,000
Coronavirus	3,500
Coxsackie virus A9	12,000
Coxsackie virus B1	15,500
Echovirus 1	11,000
Echovirus 2	12,000
Hepatites A	11,000
Infectious hepatitus virus	8,000
Influenza	3,400
Poliovirus (poliomyelltis)	6,500
Poliovirus 1	11,000
Poliovirus 2	12,000
Poliovirus 3	10,000
Reovirus 1	15,400

Bacteria	$\mu W.s.cm^{-2}$
Agrobacterium Tumefaciens	4,200
Bacillus Anthracis	4,500
Bacillus Megaterium (Spore)	9,070
Bacillus Megaterium	3,750
Bacillus Subtilis (spore)	12,000
Bacillus Subtilis	7,100
Bacillus Paratyphosus	3,200
Bacillus Enteritidis	4,000
Corynebacterium Diphteriae	3,750
Clostridium Tetani	4,900
Clostridium Botulinium	12,000
Dysentery Bacilli	2,200
Eberthella Typhosa	2,140
E. Coli	5,400
Leptospira Spp (Infectious Jaundice)	3,000
Legionella Pneumophila	2,040
Legionella Bozemanii	1,800
Legionella Dumoffii	3,000
Legionella Gormanii	2,500
Legionella Micdadei	1,500
Legionella Longbeachae	1,500
Listeria Monocytogenes	3,400
Micrococcus candidus	6,050
Micrococcus sphaeroides	10,000

Bacteria	$\mu W.s.cm^{-2}$
Mycobacterrium Tuberculosis	6,200
Neisseria Catarrhalis	4,400
Phytomonas Tumefaciens	4,400
Proteus Vulgaris	3,000
Pseudomonas Aeruginosa	5,500
Pseudomonas Fluorescens	3,500
Salmonella Enteritidis	7,600
Salmonella Paratyphi	6,100
Salmonella Typhimurium	8,000
Samonella Typhosa	6,000
Sarcina Lutea	19,700
Serratia Marcesens	2,420
Shighella Dysenteriae	4,200
Shigella Paradysenterea	1,680
Shigella Flexneri	1,700
Shigella Sonnei	2,100
Spirillium Rubsum	4,400
Staphylococcus Albus	1,840
Staphylococcus Aureus	2,600
Streptococcus Haemolyticus(A)	6,700
Streptococcus Haemolyticus(D)	9,500
Streptococcus Lactis	6,150
Streptococcus Viridans	2,000
Streptococcus Pyrogenes	2,160
Streptococcus salivarius	2,000

1. *Doll, Sir Richard (Chairman) Documents of the National Radiological Protection Board: Volume 6, No. 2 Effects of Ultraviolet Radiation on Human Health: Report of an Advisory Group on Non-Ionising Radiation.*
2. *Kowalski, W.J., and W.P. Bahnfleth. 2000. UVGI design basics for air and surface disinfection. HPAC 72 (1).*
3. *Kowalski WJ. Design and optimisation of UVGI air disinfection systems, PhD Thesis, Pennsylvania State University, 2001*
4. *Pathogen Solutions Ltd and Microsearch Ltd Antimicrobial Performance of the Medixair UVc Air Sterilisation Device. 2003*
5. *Pathogen Solutions Ltd and Microsearch Lt. Antimicrobial Performance of the Medixair UVc Air Sterilisation Device in the Sterilisation of Three Strains of Staphylococcus. 2003*
6. *Pathogen Solutions Ltd and Microsearch Ltd Evaluation of the anti-viral performance of the Medixair UVc device. 2003*
7. *Pathogen Solutions Ltd. and Quinetiq Ltd: Test Report Relating To Air Dynamics of the Medixair Unit. 2003*