Evaluation of the performance of the air cleaning device.

A Final Report prepared by

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Objectives of the study

The objective of the study was to evaluate the performance of the air cleaning device operated at the four standard fan speed settings (700, 1100, 1500 and 3150rpm). The performance will be evaluated in terms of its ability to reduce the concentration of airborne *Aspergillus fumigatus* spores in the test chamber.

Experimental Methodology

The experiments described in this report were carried out in the aerobiological test chamber at the University of Leeds, which consists of a 32.25m^3 hermetically sealed negatively pressurised chamber in which the air flow rate, temperature and relative humidity can be constantly controlled and monitored. The first experiment was carried out with the ventilation system set at 1.5 AC/hr at ambient temperature (approx 20°C) and relative humidity (approx 50%). The second experiment was carried out with the test chamber ventilation system switched off.

During the microbiological experiments the bacterial aerosols were generated using a 6-jet Collison nebuliser operating at a flow rate of 12 l/min and at a pressure of 20 psi. This was connected to the room via a 25 mm diameter pipe which terminated in a plastic sphere containing twenty four 3mm diameter holes through which the aerosol was dispersed. Air samples were collected through a plastic pipe located as requested by the client which was opposite the wall on which the device was mounted. This pipe was connected to a six stage Andersen sampler loaded with sterile agar plates. During the sampling process air passed through the sampler and the aspergillus spores were deposited onto the agar plates. The sampling time was varied depending upon the concentration of the bacterial culture with the aim of collecting between 200 and 300 colony forming units on the agar plates.

The air cleaning device was located on the wall with the top of the device approximately 30cm from the ceiling of the chamber. The power cable was plugged into one of the power sockets within the chamber and the control device was passed out through one of the access ports so the device could be operated from outside the chamber.

Test Procedure

Experiment 1

The test chamber was set up as outlined above and allowed to stabilize for 30 minutes. The nebuliser was then connected to the inlet pipe and aerosolisation of the microbial solution began and during this time the air cleaning device remained switched off. After a period of 30 minutes the concentration of bacteria in the air inside the chamber reached steady state and sampling began. A total of ten replicate samples were taken at approximately 3 minute intervals using a six stage Andersen sampler containing sterile Malt Extract Agar supplemented with Streptomycin and Novobiocin (on stages 5 and 6 only). Once all ten samples had been taken the device was switched on and operated at a fan speed of 3150 rpm. A period of 30 minutes was then allowed for the concentration of bacteria in the air inside the chamber to reach steady state once again. A further ten replicate samples were then taken at 3 minute intervals as described above. The sampling procedure described above was repeated with the device operating at fan speeds of 1500, 1100 and 700 rpm.

Once all the samples had been taken the agar plates were incubated at 40°C for 24 hours after which the number of colonies on each plate were counted. All the counts were then subjected to positive hole correction in order to account for multiple impaction (Macher 1989). The corrected counts for each set of plates (stages 5 and 6) were added together to give a total count and multiplied to give a count per m^3 of test chamber air. Each set of samples represents ten replicates taken during steady state, the first ten being the concentration without any device and the other sets of ten with the device operating at the different fan speeds. For each fan speed the mean was taken of the ten replicate samples to give a mean concentration with and without the device. This allowed the mean reduction in concentration to be calculated used to give an indication as to the efficacy of the device

In order to determine the statistical significance of the results a t-test was carried out on the two data sets (before and after). The purpose of the test is to determine whether the means of the two data sets are statistically different from each other. The test yields a p-value and the smaller the p-value the less likely the difference between the two data sets is the result of chance.

Experiment 2

This was carried out immediately after the end of experiment 1 using the same spore culture, aerosolisation and sampling techniques as described above. At the start of the experiment the ventilation fans in the test chamber were switched off and after 15 minutes the concentration of *Aspergillus fumigatus* spores in the air inside the test chamber was determined by taking five samples very quickly one immediately after the other. The device was then switched on and operated at a fan speed of 1500 rpm for 30 minutes after which ten replicate samples were taken to determine the new steady state concentration.

Results

Experiment 1

Figure 1 shows the concentration of airborne *A. fumigatus* in the test chamber during the test and Table 1 shows a summary of the data. The concentration of *A. fumigatus* during the control period ranged from 8508.8 up to 10445.2 cfu/m^3 with a mean concentration of 9201.8 cfu/m^3. The concentration dropped dramatically when the air cleaning device was operated on it maximum fan speed setting of 3150rpm. The concentration ranged from a low of 1293.3 cfu/m^3 up to 2498.2 cfu/m^3 and had a mean concentration of 1925.8 cfu/m^3. This represents a reduction of 7275.9 cfu/m^3 which is 79.1%. When the fan speed was reduced to 1500rpm the performance of the device fell slightly with an airborne *A. fumigatus* concentration of between 2219.1 cfu/m^3 and 3155.5 cfu/m^3 and a mean concentration of 2653.0 cfu/m^3. This represents a reduction of 6548.8 cfu/m^3 which is 71.2%.

When the fan speed was reduced further to 1100rpm the performance of the device decreased once again. The concentration of *A. fumigatus* ranged from 3247.4 up to 4247.4 cfu/m^3 with a mean concentration of 3726.1 cfu/m^3. This represents a reduction of 5475.6 cfu/m^3 which is 59.5%. When operated on its lowest fan speed of 700rpm the performance of the air cleaning device dropped off once again with concentrations of *A. fumigatus* in the chamber of between 5342.8 cfu/m^3 and 6558.3 cfu/m^3 and a mean concentration of 5879.8 cfu/m^3. This represents a reduction of 3322.9 cfu/m^3 which is 36.1%.

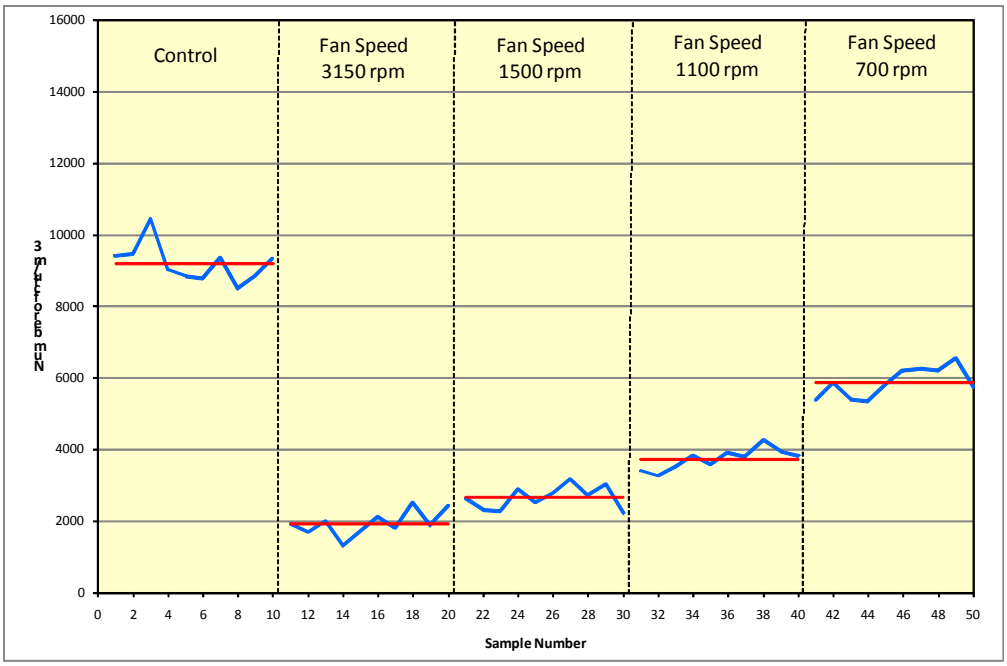

Figure 1 The performance of the air cleaning device at different fan speeds with bioaerosols of *A. fumigatus* – the blue lines represents the raw data from the ten replicate samples and the red lines are the mean concentrations over the ten replicate samples.

Table 1 Summary data for bioaerosols of *A. fumigatus*

Fan Speed (rpm)	*Concentration (cfu/m^3)*				*Reduction*		
	Before		After				
	Mean	SD	Mean	SD	cfu/m^3	%	Log
3150	9201.77	542.86	1925.80	355.70	7275.97	79.07	0.68
1500			2653.00	321.13	6548.76	71.17	0.54
1100			3726.15	296.70	5475.62	59.51	0.39
700			5878.80	421.21	3322.97	36.11	0.19

Experiment 2

Figure 2 shows the results obtained during the second experiment in which the device was operated at a single fan speed in an unventilated test chamber. During the control period the concentration of airborne *A. fumigatus* ranged from 11660.8 cfu/m^3 up to 12296.8 cfu/m^3 with an mean concentration of 12175.3 cfu/m^3. As was observed during Experiment 1 the concentration of airborne *A. fumigatus* dropped dramatically when the device was operating. The concentration ranged from 3519.4 cfu/m^3 up to 5028.3 cfu/m^3 with a mean concentration of 4332.5 cfu/m^3. This represents a drop of 7842.8 cfu/m^3 which is 64.4%

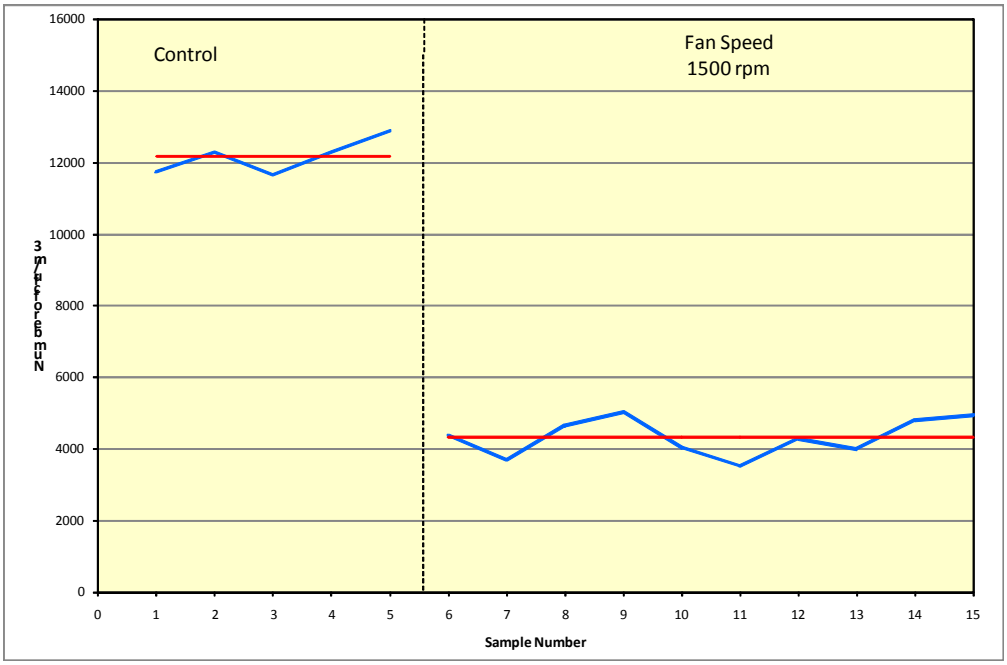

Figure 2 The performance of the air cleaning device at 1500 rpm in an unventilated test chamber with bioaerosols of *A. fumigatus* – the blue lines represents the raw data from the ten replicate samples and the red lines are the mean concentrations over the ten replicate samples.

Discussion

Overall from the data from Experiment 1 it is clear that the device performed extremely well in the chamber and achieved significant reductions in the concentrations of airborne *Aspergillus fumigatus* spores. As was observed previously the level of performance is dictated by the fan speed (Table 2) and the reason for this has been stated previously. Experiments carried out with *A. fumigatus* also supports the previous findings that the performance is relatively stable at 3150 and 1500 rpm and only starts to drop off significantly at 1100 rpm and then again at 700 rpm.

Table 2 Performance comparison between the different test bioaerosols

Fan Speed (rpm)	Percent reduction in test bioaerosol concentration		
	S. aureus	*C. difficile*	*A. fumigatus*
3150	82.1	78.9	79.1
1500	80.4	74.0	71.2
1100	52.2	55.8	59.5
700	27.4	32.3	36.1
1500 (unvent)	-	-	64.4

The results for *A. fumigatus* are more aligned to those obtained previously for *C. difficile* rather than those for *S. aureus*. This may be due to the fact that they are both spores or that both are larger than the cell size for *S. aureus*. The spore size for *A. fumigatus* is approximately 2-3µm compared to 2µm for *C. difficile* spores and 1µm for *S. aureus* cells. However *S. aureus* typically grows as a 'bunch of grapes' and therefore the individual cell

size may not be significant. This may account for the better performance of the device against bioaerosols of *S. aureus* which may be present in the air as larger clusters of cells.

Experiment 2

The results from the second experiment can be compared to those obtained at 1500 rpm in the first experiment (Table 2). It is clear from the results that when the environment is not ventilated the device is capable of achieving significant reductions in test bioaerosol concentrations. The reductions at 1500 rpm for *A. fumigatus* were 71.2% at 1.5 AC/hr and 64.4% when the chamber was not ventilated. The difference in the performance in the unventilated chamber may be due factors such as incomplete mixing of bioaerosols within the chamber which may have led to zones of higher or lower spore concentrations within the vicinity of the device or the sampling point.

Conclusions

The overall conclusions from the experiments carried out can be summarized as follows:

- The air cleaning device is capable of significantly reducing the concentration of airborne *A. fumigatus* within the test chamber.

- The performance of the air cleaning device is very dependent upon the speed at which the fan is operating.

- At fan settings of 3150rpm and 1500rpm the air cleaning device performed extremely well, reducing the airborne *A. fumigatus* concentration by more than 70%

- The performance of the device was reduced at fan settings of 1100rpm and 700rpm.

- The device is capable of significant reductions in *A. fumigatus* concentrations in an unventilated chamber

- The level of performance at 1500 rpm was slightly lower in the unventilated chamber compared to the chamber ventilated at 1.5 AC/hr.