An investigation into turbine ventilators as a potential environmental control measure to minimise the risk of transmission of TB

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INTRODUCTION

TB is an airborne infectious disease, which is spread by droplet nuclei, carrying *Myobacterium tuberculosis*, in the air. These droplet nuclei vary between approximately 1–5 µm in size[1], are able to travel long distances[2,3] and can be distributed widely throughout (hospital) buildings[4]. Droplet nuclei may remain suspended in the air until they are removed by dilution ventilation or other disinfection methods[5]. One of the recognised approaches to minimise the risk of transmission of TB is to adequately ventilate the contaminated room/space. Dilution ventilation refers to the dilution of contaminated air with "clean" air[6], thereby reducing the concentration of contaminants in the room. A higher ventilation rate can provide higher dilution capability, in turn reducing the risk of airborne infections[7]. Dilution ventilation, via natural ventilation, is considered in this research project. For the purposes of airborne Infection, Prevention and Control (IPC), the parameters of concern in ventilation design are room occupancy, ventilation flow rate and airflow pattern in the room (and building). The former reduces contaminant concentration, and the latter aims to move uncontaminated air to high risk areas, and contaminated air away from occupied areas, usually outside. The shortcomings of conventional natural ventilation strategies are well documented. The subject of this research project is to review and study the effectiveness of natural ventilation design assisted by a turbine ventilator, introduced to minimise the risk of transmission of airborne pathogens like TB.

METHODOLOGY

This research project is divided into two components, a field study and laboratory experiments. In the field study, a turbine ventilator was installed into a bedroom of a low-income house in Pretoria. This is bedroom 2 in **Figure 1**. Tracer gas (concentration decay) tests were performed to determine the ventilation flow rates and air change efficiency of the natural ventilation strategy. Four configurations, shown in **Figure 1**, were tested.

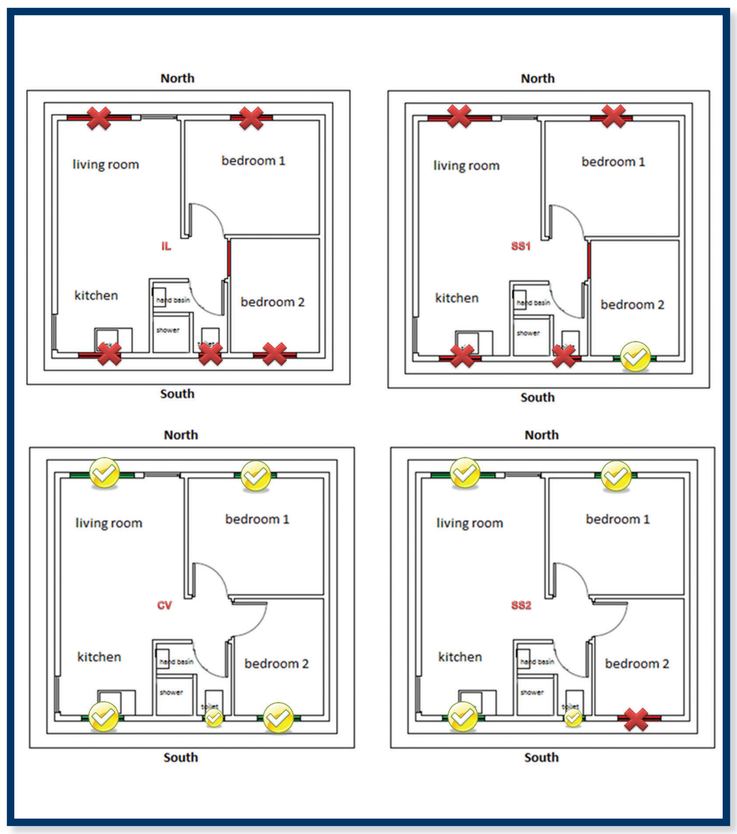

Figure 1: Natural ventilation configurations, (top left) infiltration/ leakage, (top right) single sided ventilation – case 1, (bottom left) Cross ventilation, and (bottom right) single-sided ventilation case 2

These configurations included infiltration/leakage (IL), two cases of single-sided ventilation (SS1 and SS2), and cross-ventilation (CV). Three baseline (without the turbine ventilator) and three turbine ventilator tests were performed, one each in the morning, noon and afternoon. The tests were performed between February and April 2011, which presented typical Pretoria summer days.

The turbine ventilator was then tested in a laboratory environment, under wind, buoyancy and a combination of wind and buoyancy forces. The apparatus used for the laboratory experiments is shown in **Figure 2**.

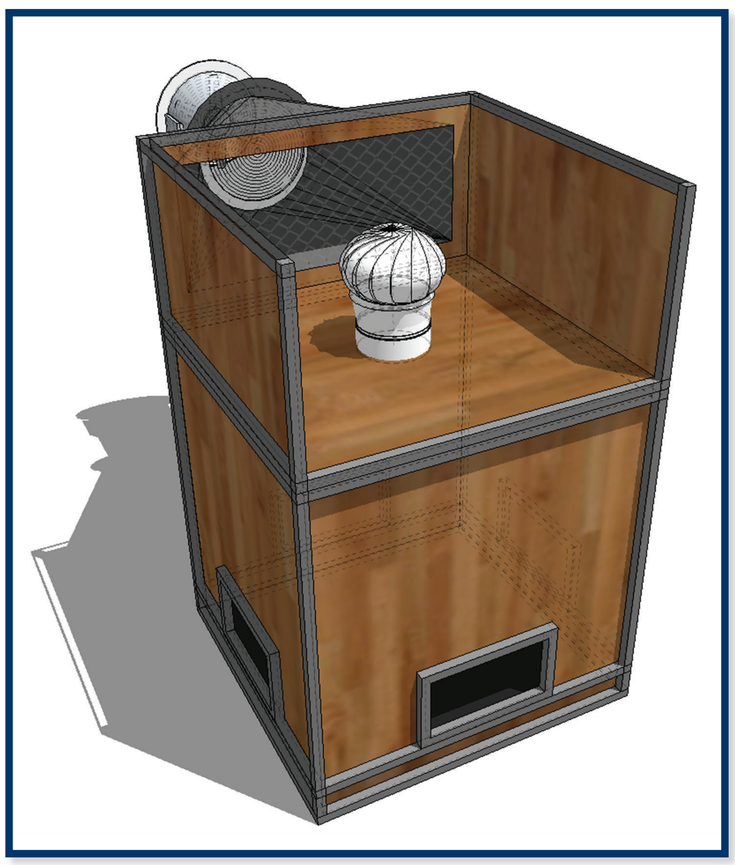

Figure 2: Laboratory experimental apparatus to investigate the performance of the turbine ventilator

The wind speeds were low, ranging from 0 to 0.5 m/s, and the temperature differential tested was in the range of 6 to 9.3°C. The in-duct velocities and centre-line velocities were investigated under these laboratory conditions to establish if, under the subjected force(s), a capture envelope, as described by Dalla Valle's equation, could be measured. This capture envelope would be used to determine if the turbine ventilator could potentially reduce the concentration of airborne contaminants in the room.

RESULTS AND DISCUSSION

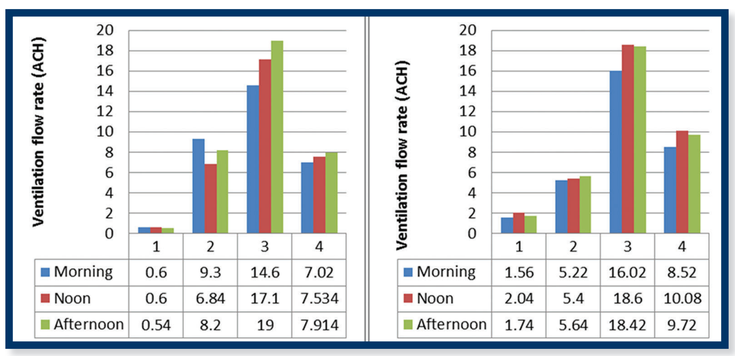

Figure 3: Ventilation flow rates for baseline and turbine ventilator tests

Results of the baseline and turbine ventilator tests are presented in **Figure 3**. In the field study baseline tests, IL, SS1, CV and SS2 mean ventilation flow rates of 0.58, 8.11, 16.9 and 7.49 ACH, respectively, were reported. The baseline tests highlight the potential of cross-ventilation, where simply opening windows and doors resulted in a ventilation rate exceeding IPC recommendations of 12 ACH for airborne isolation room. All configurations, save SS1, approached the fully-mixed case. SS1 also showed the greatest variability in ventilation flow rates. This finding is not unexpected, as air exchange in single-sided ventilation is due to wind pressure fluctuations, which varied across each test. In all tests it was found that the ventilation flow rate was dependant on the natural ventilation configuration, and openable area, and not necessarily environmental conditions.

In the turbine ventilator tests, the mean ventilation flow rates for IL, SS1, CV and SS2 were 1.78, 5.42, 17.68 and 9.44 ACH respectively. The mean ventilation flow rate increased in IL and SS2 with the installation of the turbine ventilator. In SS1 a decrease was reported. The increase in ventilation flow rate in IL was found to be due to natural convection, where the turbine ventilator merely facilitated the exhaustion of warm air.

A higher ventilation rate can provide higher dilution capability, in turn, reducing the risk of transmission of TB. How do we find that extra air change? How do we find it cost-effectively?

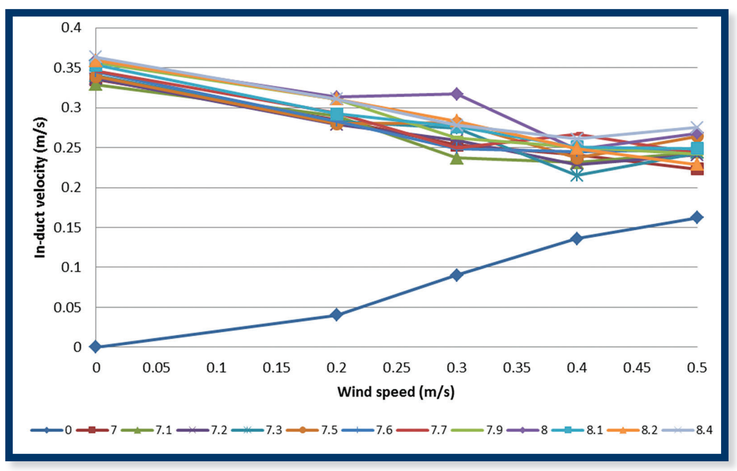

Figure 4: Summary of mean in-duct velocities through turbine ventilator in all tests

Results of the laboratory experiments are presented in **Figure 4**. In the laboratory experiments, the in-duct velocity increased with an increase in wind speed and temperature differential. For a given temperature differential, an increase in wind speed resulted in a decrease in in-duct velocity. Across all tests, no measured centreline velocity profile could be described by the Dalla Valle equation. In the wind speed tests, no capture envelope could be established. This may be due to the low wind speed test range, where the capture envelope may not extend to the first centreline velocity measuring point at 0.5D. In the buoyancy forces test, a turbulent region near the base of the turbine ventilator was realised, where the magnitude and direction of the air flowing at 1.5D continuously changed. This turbulent region was again observed in the combined wind and buoyancy forces tests, though the magnitude was smaller and occurrence less frequent. This turbulent region suggests that the flow beneath the turbine ventilator under buoyancy and combine wind and buoyancy forces would entrain, rather than exhaust, bio-aerosols.

CONCLUSION

By correlating the field study, laboratory experiments and previous (similar) studies, it was concluded that, under the tested condition, simply adding a turbine ventilator to a natural ventilation system will not reduce the concentration of contaminants in the room. The upper-room was found to be ventilated by the turbine ventilator, and the lower room ventilated according to the natural ventilation configuration. The turbine ventilator did not produce a suction force strong enough to encourage air from the room to be drawn to, or through, the turbine ventilator.

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