Determining the potential for enhanced ventilation using wind-driven roof turbines in reducing risk probability for tuberculosis transmission in households in Diepsloot, South Africa, 2019

Introduction

The scarcity of appropriate long-stay and palliative care facilities in South Africa, shortage of beds in designated hospitals as well as patient intolerance to prolonged hospital stay, compels a decision to release patients with drug-resistant forms of tuberculosis into the community before they have finished treatment. Environmental containment strategies that are cheap, consume less energy and are easy to install, such a wind-driven roof turbine ventilators, have thus been suggested as alternatives to enforced hospitalization to curb the risk of ongoing community transmission of tuberculosis.

Research aim

The aim of this study was to determine the potential that enhanced ventilation using wind-driven roof turbines in domestic homes has on the risk probability for TB transmission in Diepsloot, a resource-limited community in the Gauteng province within South Africa.

Research objectives

The objectives of this research were

- To describe the physical and social characteristics of the participating households in Diepsloot, South Africa.
- To assess the impact of wind-driven roof turbines on indoor temperature, indoor moisture levels, CO_2 concentration, room ventilation and air exchange rate in eight households (four intervention households, four control households) using a CO_2 tracer gas decay technique for measuring air changes per hour over a three-month period in Diepsloot, South Africa in 2019.

- To estimate, using the Wells-Riley mathematical model, the potential effect of wind driven roof turbines to reduce the probability of TB transmission.

Methods

Two South African seasons (winter and spring) and time of day (day and evening) were covered in the duration of the study. A baseline survey that evaluated the similarities in characteristics of the households identified in the Diepsloot Township was conducted. Using results from this survey, eight households were purposively sampled and then assigned to intervention and control groups using a pairwise comparison method, which paired a single household from the control group with a specific household in the intervention group. The pairwise comparison method determined whether households were significantly different from one another against criteria such as residential density, size of rooms, quality of structure, presence of outbuildings and occupant behaviour. Pre-intervention air monitoring was conducted to determine how similar the households were in terms of air exchange rates as these vary with activities that occur in each household. The wind-driven roof turbines were directly installed, without any ducting, in rooms in the four houses assigned to the intervention group. A carbon-dioxide (CO_2) tracer gas technique, where a CO_2 gas was injected in the house and its concentration decay recorded over time, was conducted. This was done under one condition – all windows and doors were shut. This standardized natural ventilation from open windows and doors among intervention and control houses. To establish the air exchange rate in air changes per hour (ACH), a natural logarithm of CO_2 decay concentrations was calculated. A multivariate analysis utilising mixed effects regression modelling using repeated measures was then performed to assess the impact of the wind-driven roof turbine on the ventilation rate. In addition, the Wells-Riley equation was used to determine the potential effect of the wind-driven roof turbines to reduce the probability of TB transmission. All data analysis was done using Microsoft Excel 2016 and Stata version 15 (StataCorp, 2017) with a cut-off of 0.05 used to interpret the significance of the p-values of all analyses ($p \leq 0.05$).

Results

Turbine households were noticeably cooler on average and had higher indoor-outdoor temperature ($t = 4.5$, $p < 0.001$) and humidity ($t = -7.4$, $p < 0.001$) differentials than the control households. In addition, the presence of a wind-driven roof turbine resulted in a strongly significant ($z = 2.62$, $p < 0.01$) CO_2 concentration decay than in the control household group. The average ventilation rates in turbine households ranged from 0.75 – 1.08 $m^3/h.m^2$ compared to 0.37 – 0.53 $m^3/h.m^2$ of the control households. Furthermore, for maximum occupancy, the highest ventilation rate per occupant was estimated at 6.4 L/s.person in the turbine households compared to 0.5 L/s.person for control households. The Wells-Riley model determined that approximately 65 – 79% of susceptible individuals would become infected with tuberculosis (TB) following and 8-hour exposure to an infected person in a control household. This risk was shown to nearly halve in the turbine households.

Conclusion

These results suggest a positive correlation between the presence of the wind-driven roof turbine and improved household air exchange rates. The study further supports the idea for harnessing natural ventilation using low-cost and low- maintenance wind-driven ventilation technologies on a wider scale as this presents the first steps to achieving effective ventilation for airborne infection control particularly for resource-limited communities that face facility limitations and financial constraints.

Key words

Wind-driven roof turbine; air exchange rate; carbon dioxide decay method; resource-limited setting; infection risk; Wells-Riley model