Natural Ventilation: An Evaluation of Strategies for Improving Indoor Air Quality in Hospitals Located in Semi-Arid Climates 2015

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Abstract

There is a growing concern about Indoor Air Quality (IAQ) globally in hospitals, especially after the recent outbreak of diseases like Severe Acute Respiratory Syndrome (SARS), Swine Flu (H1N1) and other airborne infections such as Tuberculosis. The semi-arid climatic condition in the study area (Maiduguri, Nigeria) which is characterised by Harmattan dust blowing from the northeast, and prevalence of mosquito insects have made the strategies to achieve acceptable IAQ more challenging. Owing to the prevalent energy shortage in the study area (Nigeria), solutions that rely on mechanical ventilation and cooling are not applicable. Thus, a sustainable ventilation strategy is required to remove indoor air contaminants while reducing the penetration of outdoor air pollutants into the hospital wards. Hence, the adoption of zero-low energy ventilation strategies is essential. The objective of this study is to determine the ventilation level from a sample of the existing hospital wards and investigating strategies to prevent the admission of Harmattan dust and mosquitoes, and yet realise acceptable IAQ.

The study utilises a questionnaire survey on a sample of five (5) hospitals to explore the hospital wards occupants' perception of the indoor air quality and ventilation. The results indicate that the occupants are dissatisfied with the indoor air quality and ventilation in these wards. The environmental conditions such as air temperature, humidity and air change rates have been measured. The air change rates in four (4) existing multi-bed hospital wards in the study area have been measured using tracer gas techniques. The result from these measurements confirms the outcome of the questionnaire survey that, the air change rates in all the four hospital multi-bed wards

studied fall short of the standard total air change rate of 6 ACH in hospital wards as enshrined by ASHRAE (ASHRAE, 2007). To study the possible design iterations that will improve the air change rates and IAQ, Computational Fluid Dynamics (CFD) was used. The CFD (Fluent 13.0) computer simulations tool was validated using results obtained from the full-scale measurements. The results show that the percentage difference between the measured and simulated air change rates is ≤ 15%, which is within the acceptable error limit.

The study explored different natural ventilation strategies in relation to opening positions, building orientation, insect screen porosity, outdoor wind speed, monthly climate conditions and pollutant dispersion. The results indicate that, out of the 17 cases simulated, the case (Case 16) with opening at both wall and roof is the best case in terms of air change rates, airflow pattern and circulation. The percentage dissatisfaction due to indoor air quality in all the 17 cases is less than 15%. The air change rates are higher in cases with external wind incidents normal to the inlet openings (90°) and then 60°, 30° and 0° respectively. The results also show that, the air change rates decreases with decreasing insect screen porosity. However the results indicate that, the higher the outdoor wind speed, the higher the air change rates. Furthermore, with incident wind normal to the inlet openings, the highest air change rates of 17.33 ACH (Case 1) and 25.21 ACH (Case 16) are experienced in the months of March and June, while the lowest air change rates of 11.33 ACH (Case 1) and 16.07 ACH (Case 16) are experienced in the month of September, and the air change rates in all the 12 moths are above the 6 ACH ASHRAE requirement. However, the quantity of dust particles received indoors increases with growing insect screen porosity. However, the quantity of dust particles received indoors increases with growing insect screen porosity. The introduction of plenums (Case 20) resulted in 133.7% increase in air change rates, compared to the case without plenums (Case 16). The introduction of the plenums also resulted in decreased particle concentration in the hospital wards.