The impact of Green Mark certification scheme on the quality of indoor environment in office buildings in Singapore

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SUMMARY
This study examined whether it is true to say that building certification schemes ensure high indoor environmental quality. Field measuring campaigns were carried out in Singapore in the office buildings certified with Green Mark scheme and in the office buildings, which are not certified. The results show that the comfort of occupants of certified buildings is improved. The risk of acute health symptoms is reduced for the occupants of these buildings and they have lower sick leave compared with the non-certified buildings. Additional benefits can be achieved by further advancements and revision of the Green Mark certification scheme.

PRACTICAL IMPLICATIONS
The results of the present work can be used to improve the method on how credits are allocated within the certification scheme especially as regards rewarding the actions resulting in improved indoor environmental quality. Present work creates also a benchmark comparing buildings certified with Green Mark scheme and other buildings. This benchmark will allow assessments of the future revisions of Green Mark scheme.

KEYWORDS
Green Buildings, Certified buildings; Offices; IEQ, Health symptoms

1 INTRODUCTION
Green building certification schemes have been introduced to assist the creation of sustainable and low energy buildings. An additional potential "spin-off" is that the buildings receiving sustainability certification are also expected to secure high indoor environmental quality (IEQ). This is despite the fact that in most of the schemes, only few credits are allocated to IEQ and there are seldom mandatory requirements pertaining to IEQ. Since only few studies examined this potential "spin-off", and those published often lack the adequate scientific rigor, the present study was initiated. It was carried out in air conditioned buildings located in the Tropical climate and had the purpose to examine IEQ and the subjective responses of occupants in buildings that were certified using the Singapore Green Mark (GM) scheme (introduced in 2005) against the buildings that could not and did not receive this certification.

2 METHODS
Cross-sectional study was carried out in pseudo randomly selected 12 office buildings in Singapore: six certified with Green Mark (GM), both Platinum or Gold level, and six without certification (NGM). The measurements were made consecutively from September to December 2014, one week per each building. One zone in a building was selected with at least 30-50 employees where the detailed measurements were made. They comprised continuous measurements of temperature, relative humidity, carbon dioxide and illuminance. From

Monday to Wednesday PM2.5, air change rates, gaseous air pollutants: HCHO, CO, CO_2; biological matter: total bacteria and total fungi were repeatedly measured. Web-based survey was developed and presented to employees working in the selected zone. They rated indoor environmental quality, satisfaction with and importance of different indoor environmental factors, their work performance and factors potentially disturbing their work, and frequency of work-related acute health symptoms. They also performed three tests: d2-test, Tsai-Partington test and short-term memory test, which examined their ability to perform work. The absence records in the year prior to the study period were collected. The results were analysed using a parametric hierarchical statistical model and the principle component analysis (PCA).

3 RESULTS

The Green Mark credits pertaining to IEQ were obtained for GM buildings and for the NGM buildings it was estimated how many credits they could potentially receive; NGM buildings scored low, as expected. Ventilation rates and PM levels were on average higher in NGM buildings compared with GM buildings. Temperatures in GM buildings were very similar, while in NGM buildings there were large variations in the measured temperatures between different buildings. Otherwise, there were no considerable differences in the measured IEQ parameters between GM and NGM buildings. Occupants of GM buildings reported significantly higher satisfaction with IEQ and indoor air quality was perceived by them to be significantly better, while the odds for the acute building related health symptoms were on average two times lower in GM buildings compared with NGM buildings. Self-estimated performance was higher in GM buildings but there were no differences in the performance of tasks measuring cognitive skills between occupants working in GM and NGM buildings. Highest proportion of employees reported thermal discomfort, air quality and distracting noise as the main factors distracting their work but except air quality, no differences were seen between GM and NGM buildings. Significantly less employees in GM buildings reported that the insufficient daylight and lack of view outside affect their work performance. Short-term sick leave was lower by one day per year among occupants of GM buildings. PCA explained >60% of the variance in the observed results: Noise, air quality, acoustic and visual privacy loaded highest as regards perceptions of IEQ, while thermal discomfort loaded highest when satisfaction with IEQ in GM buildings was concerned.

4 DISCUSSION

Being a pioneer longitudinal study in the Tropical climate, the general results of the present study are very motivating. While they show that GM schemes need further revisions they also clearly demonstrate already now the improvements in GM buildings having a positive impact on occupants. Improved satisfaction can be attributed to general higher quality of the GM buildings, its lower age, as well as general satisfaction with work conditions not only related to IEQ. It can also be related to reduced exposures and improved air quality, which is specifically demonstrated by the lower risk of health symptoms. The acoustic and visual privacy problems can be associated with the open-plan architecture. These problems have been also seen in other studies examining the impact of certified buildings on occupant perceptions, which likewise the present study showed that the self-estimated performance is higher in buildings receiving certification.

5 CONCLUSIONS

Green Mark scheme was shown to serve well the building occupants.

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