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Impact of Active Living Walls on the Air Quality in a WELL Certified Office Meeting Room: A Pilot Study

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Abstract: Research of living walls conducted in real life settings is limited. Analysis of how systems works in occupied office settings, can provide information to help reduce energy used in ventilation. Active living walls may offer an alternative to a regular mechanical ventilation as it reduces the need to extract and filter fresh air. Indoor air quality (IAQ) in the meeting room was tested in various scenarios using calibrated monitoring instruments. Preliminary results indicate that using the active living wall as the main mode of ventilation in the meeting space, temperature, CO2, and particulate matter (PM) levels were all within industrial benchmark guidelines. With further studies, different plant types, weather conditions and room sizes providing more in-depth knowledge that can be used to perfect the system, the hope of a future involving the switch from a traditional mechanical ventilation system to this innovative system may be viable.

Keywords: IAQ, Active Living Walls, Plants, Building System Performance, WELL Certification, Health and Wellbeing

1. Introduction

The main aim of this dissertation is to identify how an ALW may impact the overall IAQ of a room. The difference in levels of indoor air pollutants such as CO2 and PM were tested to provide evidence of how effective the system was in a medium sized meeting room. Another aim of the dissertation is to check how feasible it is to replace the use of the current VAV mechanical ventilation system with this ALW. This is so that an energy efficient alternative to the current VAV system can be suggested.

To execute the main aims of the project, different objectives are to be accomplished. The first objective is to test the overall IAQ in a meeting room in the Cundall's London office over three separate iterations: (i) with mechanical ventilation, (ii)only with the ALW and (iii) without any ventilation (control). The second objective of the project is to synthesize the large dataset which will be gathered at the end of the experiment by the various equipment placed in the room to test for temperature, RH, PM and CO2. The final objective is to analyse the synthesized data to find out how the IAQ of the room fares with the three different ventilation setups. This is done by referring to government or industrial guidelines and benchmarks, as well as comparing the outcomes with research outcomes in the literature review. A by-product of this study was to identify how well the space adheres to the WELL Building certification the company had attained a year ago.

2. Method

The experiment is conducted in a meeting room in the Cundall's WELL Certified office located in central London. The accreditation entails that the building elements contained within the office contributes to the high standards of air, water, light, comfort and mind requirements as defined by the WELL organization. The company has established that several measures were taken to maintain good air quality. This include the installation of MERV-13 filters and low VOC materials and finishing, UV treatment to cooling coils, and ductwork protection from dust ingress in ventilation systems.

The room being tested is one of the main meeting spaces in the office. The nature of the space indicates that the room is used for short periods of time, sporadically. For ventilation in this meeting room, a VAV system with a single rectangular boundary diffuser is implemented. There are two non-operable windows placed in the walls of the space that are external. The active living wall system is located by the centre of the longer wall, so that it could provide a throw of air that could reach most of the occupiable spaces in the room.

The experiment tested different factors over the three iterations: temperature, relative humidity, CO_2 and PM. The equipment used were calibrated and carefully placed around the room such the most representative values of the air quality was measure. Three HOBO monitors were placed in different parts of the room to record temperature and relative humidity. An IBEM monitor was used to measure the CO_2 levels in the room, and DustTrack monitor was used to measure the PM levels. Both monitors were placed in the centre of the conference table in the middle of the room. Further to ensuring their proper calibration, care was ensured that the systems were set to record at one minute intervals.

The raw dataset collected for each factor were thereby organized to identify patterns or differences within the three iterations. Both descriptive and inferential statistics were used to provide mathematical evidence of how the results of the measured factors fared in each iteration.

3. Results and analysis

3.1 Temperature and RH

The slight differences in temperature and RH outlined below can be credited to the change in locations. HOBO-1, shows higher temperatures as compared with the other HOBO temperature averages. This is because HOBO 1 was placed close to the window, and may have registered warmer temperatures during periods of sun penetration through the glazing. HOBO-2 recorded higher RH values than the other units. This unit was placed near the plant wall system, and it is possible that the watering system of the plant may have affected this outcome.

Table-1-: Temperature and RH Value Summary Table

Iteration	HOBO #	Mean Temperature (˚C)	Standard Deviation temp	Mean RH (%)	Standard Deviation RH (%)
1 (Only VAV--7th-9th June)	1	22.95	0.130	51.20	0.2143
	2	22.20	0.120	60.61	0.2585
	3	22.81	0.070	51.29	0.0545

2 (Only ALW 10th-12th June)	1	23.35	0.072	57.68	0.0536
	2	22.54	0.052	61.46	0.3705
	3	22.90	0.400	58.00	0.0536
3 (Control Experiment: 13th June)	1	23.80	0.370	59.29	0.0423
	2	22.89	0.360	62.44	0.0464
	3	22.93	0.420	51.67	0.1304

3.2 CO_2

The values show that the overall CO_2 levels in the room were well within all the industrial benchmarks. The overall low level of CO_2 levels can be attributed to the fact that there were virtually no people occupying the room and the fact that the building systems worked efficiently to provide adequate fresh air into the space. An IES simulation of the building was conducted to estimate CO_2 levels in the room, with people in it. The results of the simulation show that the build-up level peaks to 1000PPM, which is the highest level recommended by CIBSE, and is 400PPM higher than the WELL Standard.

Table-2: Average CO2 Values for all Iterations

Iteration	Average CO2 Value
1	497
2	440
3	552

3.3 PM

The results from the DusTtrak equipment shows a few main findings. The first finding indicates that there is a gradual increase in the buildup of the average PM values throughout the experiment. The values are all, however, within the maximum limit set by the WHO guidelines. The second finding indicates, that the plants or ventilation did not seem to have much impact on the PM levels in the room. The trend in the graph does show, however, that the best and lowest average results of PM in the room was recorded in the iteration whereby the mechanical VAV system was turned on.

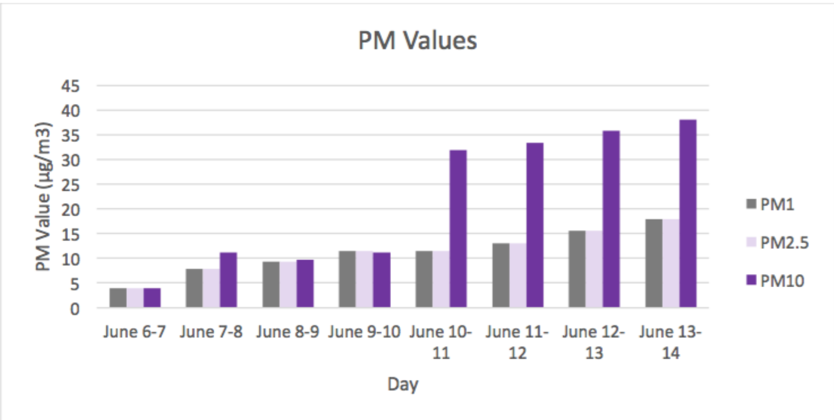

Figure 1: PM Values

4. Discussion

4.1 Temperature and Relative Humidity (RH)

As expected due to results from research and general building physics calculations, the highest temperature values, which were still well within the maximum limits set out by the CIBSE guidelines, were found in the iteration without any ventilation system (K. Charles, 2005, CIBSE, 2006). In terms of IAQ, the mean temperatures for all the iterations show that the chances of getting spores or mould growth in the room is unlikely, as research shows higher temperature levels, especially in conjunction with higher RH levels contribute to significant microbiological growth (Dallongeville et al., 2015, Annila et al., 2017, Dannemiller et al., 2017, Hurraß et al., 2017). The results show that the overall indoor temperature is one free from overheating which can contribute to thermal discomfort. This can further entail that higher employee morale can be attained in the working environment, as well as lower chances of occupants susceptible to SBS, and the prevention of lowered productivity due to thermal discomfort. These outcomes are also in line with the WELL certification the company aspires to maintain.

The results showed that there were slightly elevated levels of RH in the room upon the use of the ALW. The recorded mean level was on the higher side of the recommended values as indicated by CIBSE (2016). Care must be given to the fact that the system used for the experiment was only half full and did not have too many plants. Therefore, when ameliorating the system for permanent use, it is safe to assume more plants would be incorporated into the ALW unit. This may result to a further increase in the overall RH levels due to plant transpiration. Therefore, a supplementary humidification system is proposed to be used in conjunction with the system to avoid possible IAQ issues such as spores and mould (Mendes et al., 2015, Duchaine, 2016, Tham et al., 2017).

4.2 CO_2

The overall CO_2 levels within the first two iterations with some form of ventilation indicated good levels of IAQ (as pertaining to carbon levels). The constant air circulation within the room, seemingly aided the maintenance of the mean CO_2 values for both iterations to be well below 1000 PPM which is deemed safe and recommended for an indoor environment (CIBSE, 2011).

The results show that the iteration with the ALW provides lower CO_2 levels that the other two iterations. This indicates that the use of plants in the active wall may contribute to the overall reduction in the CO_2 value. The reduction however, while noticeable, was not too drastic, but that may be credited to the fact that the overall number plants or surface area of their leaves were inadequate (Suhaimi et al., 2016). The spider plants that were used for the ALWs in this experiment were not grown to a full capacity and there were missing pots of plants in the shelving unit. It can be noted that, had a plant recommended by the outcome of the experiment conducted by Suhaimi et al. (2016) such as Prayer Plants were to be incorporated, or if there were more of the same plants, the overall reduction in CO_2 may have been more pronounced.

4.3 PM

The results indicate that the overall PM levels within the room during the iterations that included some form of ventilation were within the range of PM values set out by the WHO. The DustTrak monitor results especially suggest that the levels of PM were low when the mechanical ventilation system was turned on. This result is consistent with the expectation that a mechanical ventilation system with a MERV13 filter would have relatively low levels of indoor pollution due to the effectivity of the filter units. The results of the PM values in the first iteration is a testament to how effective the mechanical ventilation system is in maintaining appropriate IAQ standards for the WELL certification.

The PM values in response to the ALW mechanical ventilation system shows that there is a definite increase in the level of PM in the room in that iteration. The plants did not prove to be as effective a filter system as the MERV13 filters in the main mechanical ventilation system. The results did indicate a spike in the values in the iteration without any ventilation systems turned on. This indicates that the active plant wall was comparatively effective in the filtration of the PM levels. The research, however, did outline a set of results that indicated that the use of plants provided greater reduction of PM levels. The lack of such effective results can be credited to the fact that the plants used for this experiment may not be as effective as those used by the research. It would be beneficial for further research that a completely filled plant wall system with plants with larger leaves be used to test impact on PM levels.

4.4 Feasibility of replacing the VAV ventilation systems with the ALW

The results indicate that the ALW performed well as a filtration system in the room and they entail that the ALW can, if carefully monitored, be used as a replacement for the current mechanical ventilation system. It should be noted, however, that the building does rely on the system for thermal comfort purposes as there are no supplementary radiators or external cooling devices. Therefore, the sole use of the ALW can be endorsed only during mild climate conditions, when heating or cooling is not mandated for thermal comfort.

This outcome extends to the premise that in a space that that is designed to implement a natural ventilation strategy, the use of an ALW could prove to be quite beneficial. The use of an ALW for the ventilation purposes in a small to midsize room employing the natural ventilation method can be beneficial as the need to open windows for ventilation is reduced which can help reducing heat losses in the winter or coolth in the summer, thereby reducing the energy required to thermally condition the space, while simultaneously providing adequately filtered air for ventilation purposes.

It can also be advised, after observing the results, that the air from the ALW be recirculated to the duct work of the VAV mechanical ventilation system. This can help in the reduction of energy required to extract fresh air from outside which can prove to be beneficial during the time of harsher weather conditions. The calculations and resulting psychrometric chart found in Appendix-A, shows that energy is reduced if a percentage of air is recirculated within a representative VAV system modelled through IES. Therefore, even if a VAV system is still required, using the ALW as an air purification unit may prove to be a solution to the energy intensive process of extracting fresh external air for the room.

5. Conclusions

Results of the first iteration highlights how well the current VAV system works as temperature, RH, CO_2 and PM levels are all within the industrial guidelines recommendations. This entails that there is adequate IAQ for the employees to work well and comfortably. This accomplishes the underlying premise of the WELL accreditation.

It can be concluded from the results that the ALW performs well in reducing the overall CO_2 levels. The results indicate that the iteration with only ALW had the lowest levels of CO_2. It can be noted also that the ALW tested also showed a lower PM values within benchmarks when compared to the iteration with no ventilation system in the room. There had been no noticeable change in the overall temperature, but there is a slight increase in RH.

It can be advised that once the ALW is modified to meet the ventilation requirements of the room such that it does not stop working due to overload and is filled with adequate number of plants, it may be used as an alternative to the current VAV system in mild summer conditions. This can be a sustainable alternative to extracting fresh air for good IAQ purposes which can help reduce the overall energy consumption in the building. Upon further research, involving different seasons, plant species and sizes of the systems, the ALW may one day be a viable option to be a stand-alone energy efficient ventilation system.

6. References

K. CHARLES, J. T. R. A. R. J. M. 2005. IAQ and Thermal Comfort in Open-Plan Offices. Construction Technology Update 64.

CIBSE 2006. Environmental Design: CIBSE Guide A, Chartered Institution of Building Services Engineers

DALLONGEVILLE, A., LE CANN, P., ZMIROU-NAVIER, D., CHEVRIER, C., COSTET, N., ANNESI-MAESANO, I. & BLANCHARD, O. 2015. Concentration and determinants of molds and allergens in indoor air and house dust of French dwellings. Science of The Total Environment, 536, 964-972.

ANNILA, P. J., HELLEMAA, M., PAKKALA, T. A., LAHDENSIVU, J., SUONKETO, J. & PENTTI, M. 2017. Extent of moisture and mould damage in structures of public buildings. Case Studies in Construction Materials, 6, 103-108

DANNEMILLER, K. C., WESCHLER, C. J. & PECCIA, J. 2017. Fungal and bacterial growth in floor dust at elevated RH levels. Indoor Air, 27, 354-363.

HURRAS, J., HEINZOW, B., AURBACH, U., BERGMANN, K.-C., BUFE, A., BUZINA, W., CORNELY, O. A., ENGELHART, S., FISCHER, G., GABRIO, T., HEINZ, W., HERR, C. E. W., KLEINE-TEBBE, J., KLIMEK, L., KÖBERLE, M., LICHTNECKER, H., LOB-CORZILIUS, T., MERGET, R., MÜLLENEISEN, N., NOWAK, D., RABE, U., RAULF, M., SEIDL, H. P., STEIS, J.-O., SZEWSZYK, R., THOMAS, P., VALTANEN, K. & WIESMÜLLER, G. A. 2017. Medical diagnostics for indoor mold exposure. International Journal of Hygiene and Environmental Health, 220, 305-328

MENDES, A., BONASSI, S., AGUIAR, L., PEREIRA, C., NEVES, P., SILVA, S., MENDES, D., GUIMARÃES, L., MORONI, R. & TEIXEIRA, J. P. 2015. IAQ and thermal comfort in elderly care centers. Urban Climate, 14, 486-501

DUCHAINE, C. 2016. Assessing microbial decontamination of indoor air with particular focus on human pathogenic viruses. American Journal of Infection Control, 44, S121-S126

THAM, R., VICENDESE, D., DHARMAGE, S. C., HYNDMAN, R. J., NEWBIGIN, E., LEWIS, E., O'SULLIVAN, M., LOWE, A. J., TAYLOR, P., BARDIN, P., TANG, M. L. K., ABRAMSON, M. J. & ERBAS, B. 2017. Associations between outdoor fungal spores and childhood and adolescent asthma hospitalizations. Journal of Allergy and Clinical Immunology, 139, 1140-1147.e

CIBSE 2011. Module 27: Indoor Air Quality, CPD 27

SUHAIMI SHAMSURI, M. M., LEMAN, A. M., HARIRI, A., RAHMAN, K. A., YUSOF, M. Z. M. & AFANDI, A. 2016. Profiling of Indoor Plant to Deteriorate CO2 Using Low Light Intensity. MATEC Web Conf., 78, 01011