Can plant walls improve indoor air quality?

Michael W Zavattaro

School of Life Sciences

University of Technology Sydney

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Certificate of Original Authorship

This research is supported by an Australian Government Research Training Program Scholarship. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Figure 4.2

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Figure 4.3

C. comosum: a) $PM_{2.5}$ concentration reduction (mg/m^3). Comparison between no modules (background reference); modules with no active fans; with active fans at 50% operation speed (4.9 L/s); and 100% fan speed (9.7 L/s). B) *E. aureum* $PM_{2.5}$ concentration reduction (mg/m_3); comparisons as above (means ± SEM, $n = 3$).

Figure 4.4

C. comosum: a) benzene concentration reductions (%) over a 12 h period, with starting concentration ~10 ppm. Comparison of reduction rates with no active fans (ambient diffusion), fans at 100% operational speed (9.7 L/s); plus background reference tests. B) *E. aureum* benzene concentration reductions (%) over a 12 h period, under same conditions as above.

Figure 5.1

The seven sample sites tested for IAQ: a) public library; b) packaging and courier company; c) Hunter St café; d) UTS administration centre; e) UTS conference centre; f) insurance company; g) child day care centre.

Abbreviations

ABPA – Allergic bronchopulmonary aspergillosis

AHU – Air handling unit

Air NEPM – National Environment Protection Measure for Ambient Air Quality

ANSI - American National Standards Institute

ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers

CFU – Colony forming units

CO_2 – Carbon dioxide

CO – Carbon monoxide

DEH - Department of the Environment and Heritage

DFG - Deutsche Forschungsgemeinschaft

EPA – Environmental Protection Agency

HVAC – Heating, ventilation and air conditioning system

IAQ – Indoor air quality

NAAQS – U.S. National Primary and Secondary Ambient Air Quality Standards

NEPC – National Protection Council

NHMRC – National Health and Medical Research Council

NO_2 – Nitrogen dioxide

OAQ – Outdoor air quality

OSHA – Occupational Safety and Health Administration

$PM_{2.5}$ – Particulate matter with a maximum diameter of 2.5 μm

PM_{10} - Particulate matter with a diameter between 2.5 - 10 μm

PPM – Parts per million

SBS – Sick-building syndrome

SO_2 – Sulfur dioxide

UAP – Urban air pollution

U.S. EPA – The United States Environmental Protection Agency

VOC – Volatile organic compounds

WHO – World Health Organisation

Abstract

Urban air quality has deteriorated over the last 60 years, and air pollution has become a serious threat to the health and wellbeing of city dwellers. It is known that indoor air can be at least 3-5 times more polluted than outdoor air, and as most office workers spend 90% of their time indoors, this presents significant health and productivity concerns. Plants have been shown to provide psychological and physiological benefits to building occupants. It is only in recent years that their phytoremediation benefits have been established, as potentially sustainable indoor biofilters. The aim of this study was to investigate the proficiency of a novel, optionally fan-aerated, plant wall system, in removing four major indoor air pollutants, CO_2, PM_{10}, $PM_{2.5}$ and VOCs. The planted modules were comprised with either *Chlorophytum comosum* or *Epipremnum aureum*. An airborne fungal spore assay was also conducted, to determine the biosafety of the system in an office environment. It was found that the plant walls did not proliferate hazardous fungi such as *Aspergillus fumigatus*, nor increase the fungal spore density in the office tested. Their density was less than one twentieth of the recommended WHO maximum of 500 cfu/m^3. With sub-substrate fans operating, the modules were also highly efficient in reducing concentrations of PM_{10} and $PM_{2.5,}$ by upwards of 70% in 10 min, well below the Australian maxima. Benzene, a model VOC, was reduced by more than 60% over a 12 hr period, however the walls were more effective in passive rather than active mode. Plant uptake of PM_{10}, $PM_{2.5}$ and VOCs continues night and day. The walls were also shown capable of significantly reducing CO_2 levels. However, as expected, the uptake was highly dependent on the light intensity. Finally, an *in situ* survey of seven city buildings, all using air-conditioning systems (HVACs), found that the same type of plant wall modules did have some effect in reducing indoor CO_2 levels, depending on the areas of the walls involved. These findings show potential for plant walls to be used as a complementary means of reducing building air pollution, and hence the lowering energy usage of current HVAC systems. This innovation could reduce overall building energy use, thus improving future urban sustainability. To achieve this goal, further research is needed on the ability of a range of indoor plant species to reduce CO_2 concentrations, and optimum formulations for substrates, to ensure maximum improvements of building IAQ.