

Botanical Biofilters for the Phytofiltration of Urban Air Pollutants

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Thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy under the supervision of Dr Fraser Torpy and Dr
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Certificate of Original Authorship

I, Thomas Pettit, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Life Sciences at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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Format of Thesis

This thesis is submitted as a *thesis by compilation*. This thesis consists of seven chapters. Chapters 1-6 represent separate articles, all of which have been peer-reviewed, accepted and published in scientific journals. As such, parts of this thesis are presented verbatim to their published form; consequently, some repetition occurs in regards to themes and style. To prevent unnecessary duplication, a single reference list has been provided at the end of the thesis.

This thesis is a compilation of my own work with guidance from my supervisors and additional assistance from others. I conceptualized my research, designed the experiments including choice of methods and instrumentation, conducted all data collection and analysis, and wrote the manuscripts. My supervisors and co-authors proof-read and edited the final peer reviewed manuscript versions. Publication details and contributions of co-authors are detailed below.

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List of Abbreviations

ANOVA: Analysis of variance

CADR: Clean air delivery rate

CO₂: carbon dioxide

df: Degrees of freedom

HDPE: High density polyethylene

HSD: honestly significant difference

HVAC: Heating, ventilation and air conditioning

GAC: Granular activated carbon

MERV: Minimum efficiency reporting value

NASA: National Aeronautics and Space Administration

NO: Nitrogen oxide

NO_x: Oxides of nitrogen

NO₂: Nitrogen dioxide

O₃: Ozone

PERMANOVA: Permutational analysis of variance

PM: Particulate matter

PM_x: Particulate matter, where x denotes the maximum aerodynamic diameter of the particles in μm .

ppb: Parts per billion

ppm: Parts per million

PVC: Polyvinyl chloride

SPRE: Single pass removal efficiency

TSP: Total suspended particles

TVOCs: total volatile organic compounds

VOCs: volatile organic compounds

WHO: World Health Organisation

Abstract

Air quality is of emerging importance due to the rapid growth of urban populations that are exposed to air pollution in both indoor and outdoor environments. As a potential solution, active green walls or botanical biofilters have been developed to assist in the removal of air pollutants directly from environments where people live. Through the use of active airflow, these vertically orientated, botanical systems pass a contaminated airstream through the plant growth substrate and foliage to filter air pollutants. The work presented here explores the capacity of active green walls to filter air pollution through laboratory, indoor and outdoor studies. Firstly, laboratory-based experiments revealed that the single pass removal efficiency (SPRE) of different volatile organic compounds (VOCs) by active green walls is influenced by the VOC's chemical properties, with average SPREs ranging from 19.76-96.34%. Modelling revealed that highly polar, small molecular weight molecules were removed with greatest efficiency. Secondly, pilot-scale trials assessed an active green wall's pollutant removal within a classroom, with average total VOC and PM concentrations reduced by ~28% and ~42.6% respectively, over 30 min trial periods, compared to levels with no green wall but having a HVAC-filtration system in operation. Thirdly, botanical biofiltration of NO₂ was assessed at ambient and elevated concentrations within a closed-loop flow reactor, while the concentrations of NO and O₃ were simultaneously monitored. Biofilter treatments using two plant species (*Spathiphyllum wallisii* and *Syngonium podophyllum*) exhibited exponential decay for the biofiltration of all three pollutants at ambient concentrations. Furthermore, both treatments removed elevated concentrations of NO and NO₂. Subsequently, botanical biofilters were field-assessed for the filtration of traffic associated air pollutants – NO₂, O₃ and PM_{2.5} – from roadside ambient air in Sydney, Australia. Over two six-month research campaigns, all of the tested systems filtered NO₂, O₃ and PM_{2.5} with average SPREs of up to 71.5%, 28.1% and 22.1% respectively. Clean air delivery rates of up to 121 m³/h, 50 m³/h and 40 m³/h per m² of active green wall were achieved for the three pollutants respectively, with pollutant removal efficiency positively correlated with their ambient concentrations. An additional trial identified that active green walls filtered elevated air pollutant concentrations associated with the *Black Summer* wildfires, with average SPREs of 63.17%, 38.79% and 24.84% for NO₂, O₃ and PM_{2.5} respectively. These cumulative

findings reveal that active green walls may have the capacity to play an important role in enhancing air quality and reducing air pollution exposure.