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Phytoremediation of air pollution

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CLIMATE FOR CHANGE | A BETTER AIR QUALITY FUTURE
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Phytoremediation of air pollution

Table 1 Top productive countries/regions on botanical research in the indoor environment.

Countries/ Regions	TP	%TP	Years									TC
			2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
USA	71	19.24	7	6	3	2	5	0	3	5	4	6	2006
AUSTRALIA	40	10.84	0	0	2	3	0	1	4	8	9	3	1414
CHINA	38	10.29	3	4	1	1	3	0	3	3	8	6	427
SOUTH KOREA	27	7.31	2	2	1	2	4	2	0	1	0	4	849
THAILAND	22	5.96	1	1	1	2	1	5	1	2	4	3	378
POLAND	17	4.60	1	0	0	0	4	2	1	0	5	3	494
IRAN	16	4.33	0	3	2	0	1	2	0	4	1	3	145
SPAIN	16	4.33	0	1	1	4	0	1	2	3	1	1	381

Tan et al 2022

Air pollution removal by the urban forest

- 'Green spaces' have significant effects in removing PM (Dierner and Mudu 2021), CO, SO_x, NO_x, O_3 (Wei et al 2017), anthropogenic VOCs (Irga et al 2018)
- Reductions highly system and *area* dependent
- 'BVOC' emissions also system dependent: can increase air pollution (Roeland et al 2019)
- Sequestration of CO_2 (Nowak et al 2013)
- Health benefits have been recorded for adjacent populations (WHO 2021)
- *Many other services*: UHI, noise reduction, stormwater management, physical, mental, emotional, psychological benefits, biodiversity, aesthetics, property values etc. (Roeland et al 2019)
- *A universal core component of sustainable cities*

Air pollution removal by plants

7,000 trees will be planted in London to improve air quality

The Mayor of London, Sadiq Khan has announced that in order to help reduce air pollution and carbon dioxide (CO_2), thousands of trees will be planted across 20 boroughs in London.

Paris plans to go green by planting "urban forest" around architectural landmarks

India Block | 26 June 2019 | 21 comments

4th September

Southend: 'Plant grass and plants on top of our town's bus stops to help the environment'

By Ellis Whitehouse | @E_Whitehouse293
Senior Reporter

Asia Pacific

Pakistan seeks to bring fresh air to polluted cities with 10 billion trees

By Umar Farooq

Experts identify 'super-plant' that absorbs roadside air pollution

Bushy variety of cotoneaster works best in areas of heavy traffic, say researchers, while other plants can cool buildings or reduce flooding

HOME » NEWS » INDIA » INDORE TO PLANT 2 LAKH PLANTS TO IMPROVE AIR QUALITY BY INDEPENDENCE DAY

1-MIN READ

Indore to Plant 2 Lakh Plants to Improve Air Quality by Independence Day

Plants improve indoor air quality

NASA studies (Wolverton *et al*. 1983–1997) showed that plants improved air quality in sealed spacecraft simulators

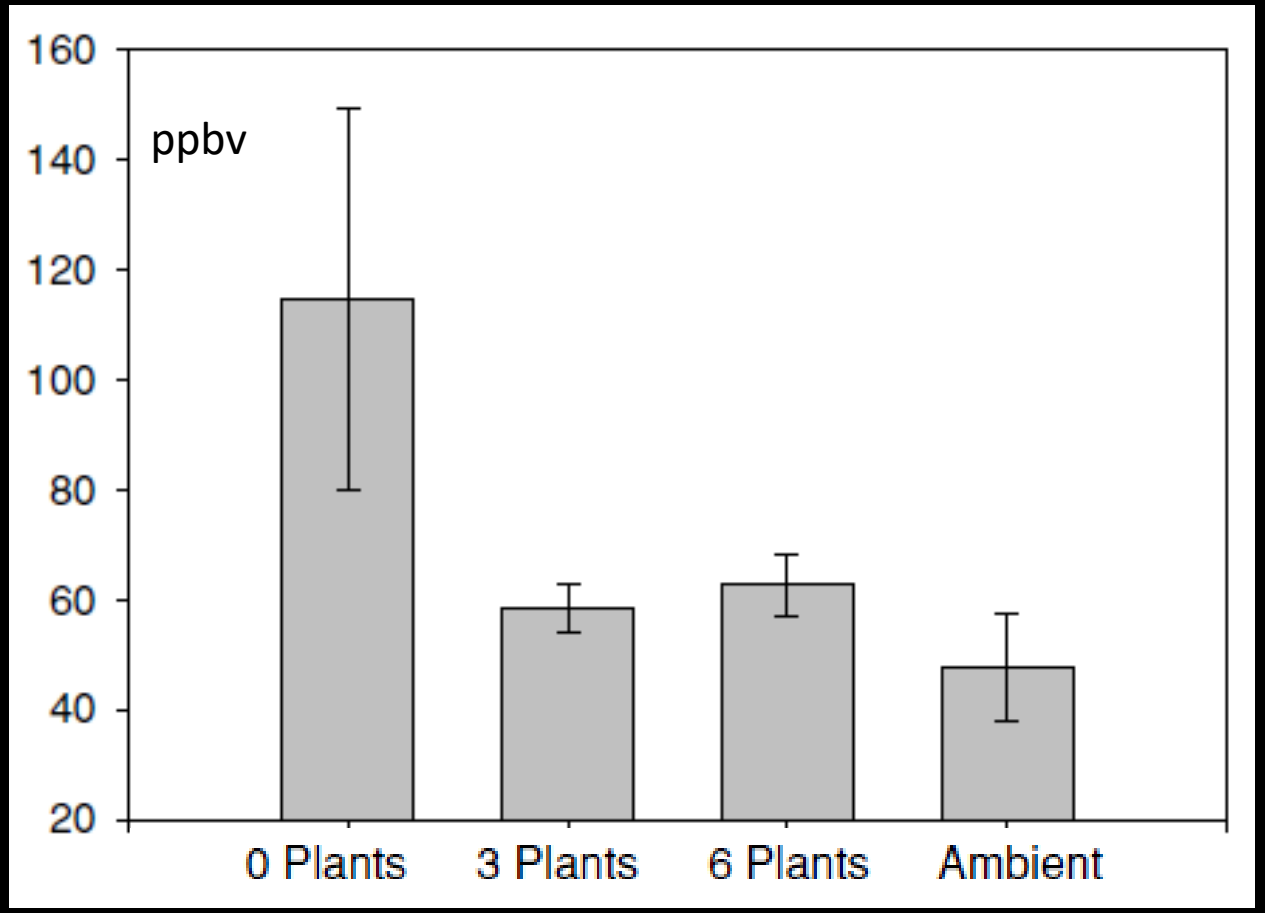
35 y of research:

All potted plants can remove all VOCs

Mainly due to substrate microbial metabolism

Consortial processes, plant involvement

In situ: TVOC

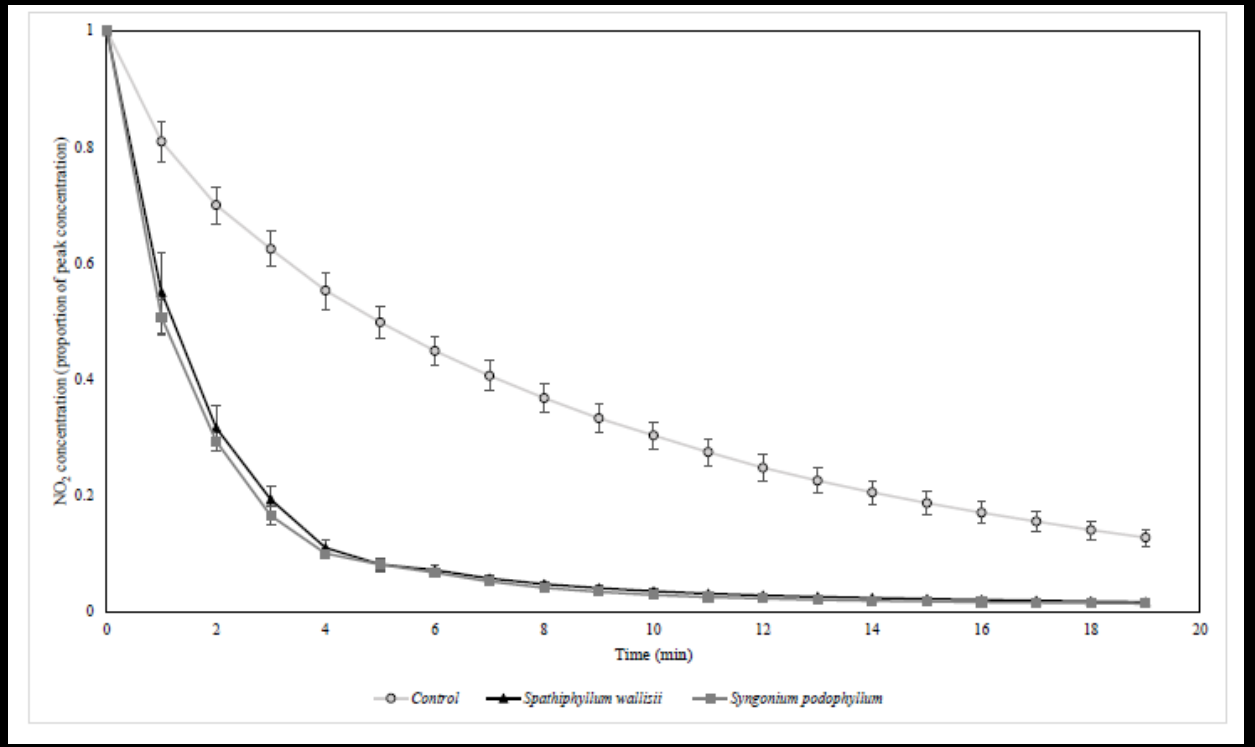


Wood et al. 2006

Mechanisms of removal: SO_x and NO_x

- Plant-mediated
- Removal exceeds natural decay
- Dry deposition on leaf surfaces and direct dissolution into water film on plant surfaces and stomatal uptake, reaction with plant tissues

- $BVOCs + NO_2 \rightarrow O_3$

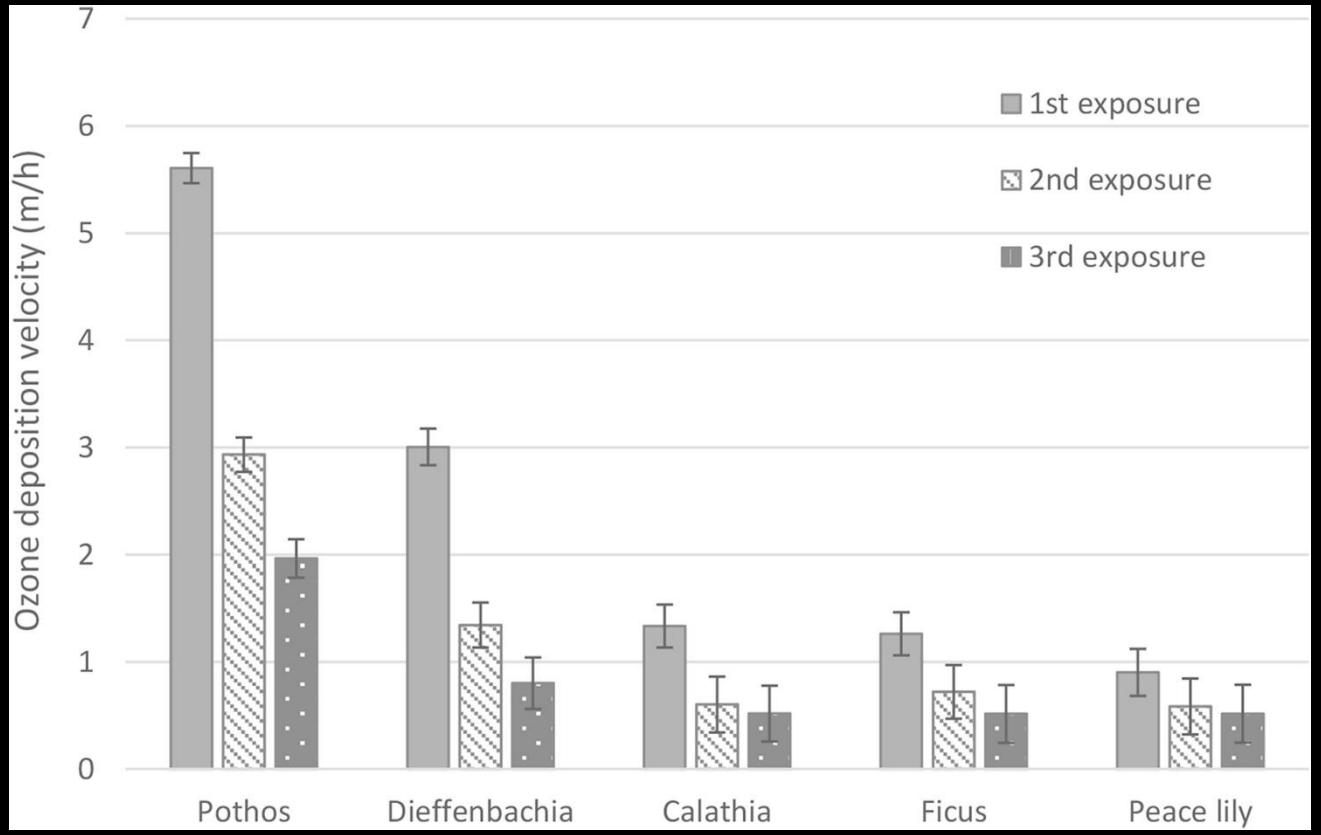


Elevated NO_2 biofiltration / ambient light

Pettit et al. 2020

Mechanisms of removal: O_3

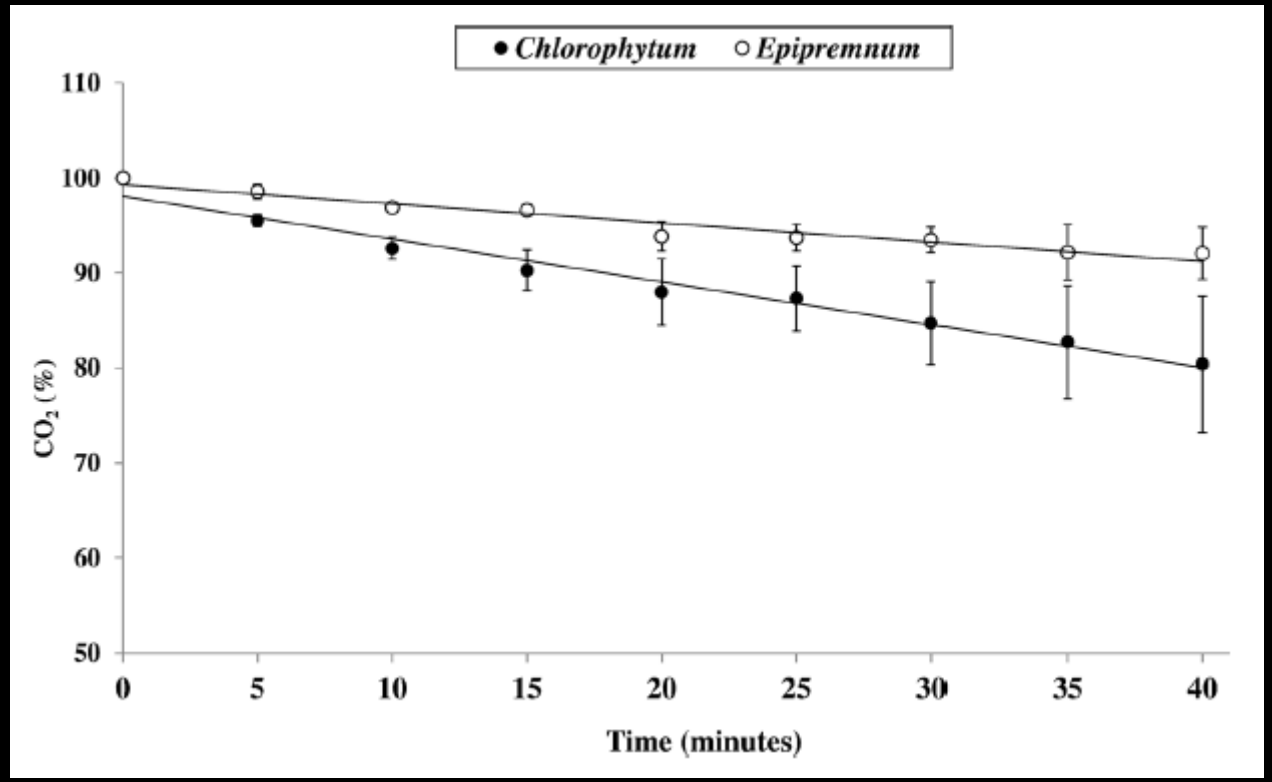
- Highly species dependent
- Net O_3 removal in most studies
- Significant leaf area: room volume required for meaningful effects
- Long term plant health effects unknown



Abbass et al 2017

Mechanisms of removal: CO_2

- Photosynthetic draw down
- Species and light dependent
- Valuable *in situ* effect sizes plausible



Draw down in test room from 1000 ppmv CO_2; 1 m^2 green wall, 100 µmol m^{-2} s^{-1} light

Torpy et al. 2017

Mechanisms of removal: PM

- Interception and adhesion to leaves
- Effected by leaf morphology and arrangement, chemical composition of epicuticle
- Retention dependent on PM size and composition

- Retention significant but proximal reductions hard to detect
- Resuspension may occur
- Temporary retention for most PM

Development of phytosystems for air pollution removal

- All pollutant removal is rate limited by diffusion (Irga et al 2018)
- *Pollution removal effect sizes by passive vegetation are low per unit of green space*

Junglefy, Australia

CADRs of passive indoor plants

Pollutant	CADR ($m^3.h^{-1}.plant^{-1}$)	Reference
Formaldehyde	**0.22**	Aydogan and Montoya (2011)
Benzene	**0.038**	Orwell et al. (2004)
Toluene	**0.050**	Orwell et al. (2006)
Xylene	**0.068**	Orwell et al. (2006)
TCE	**0.0073**	Wolverton et al. (1989)
Chloroform	**0.00095**	Zhang et al. (2018)

Cummings and Waring 2020


This won't work very well…

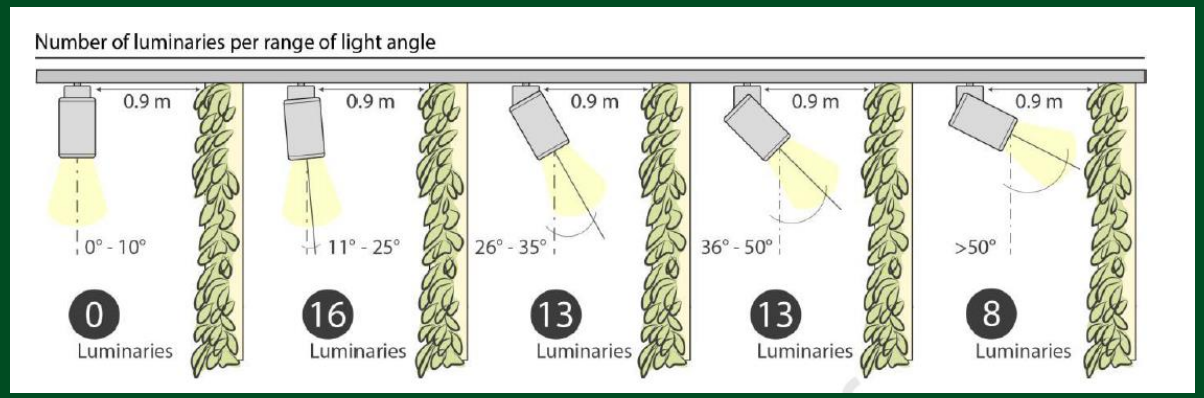
- Planting density increased
- Improved substrate exposure
- All pollutant removal rates increased

Development of phytosystems for air pollution removal

Pollution removal efficiency can be improved

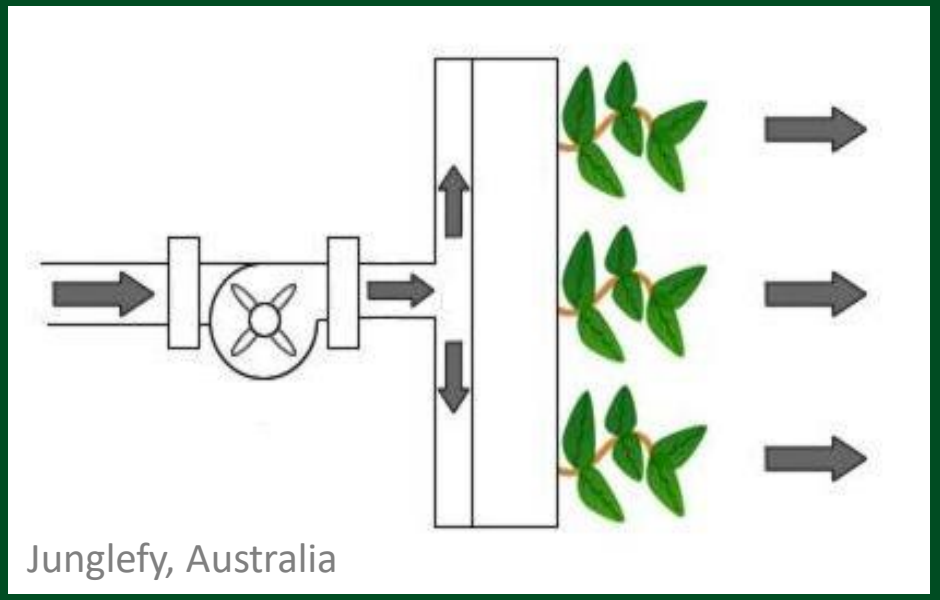
- Effective lighting (Dominici et al 2021)
- Pollutant targeting (Pettit et al 2019)
- Substrate modification (Pettit et al 2018)
- GM plants (Zhang et al 2018)

Paull et al 2019



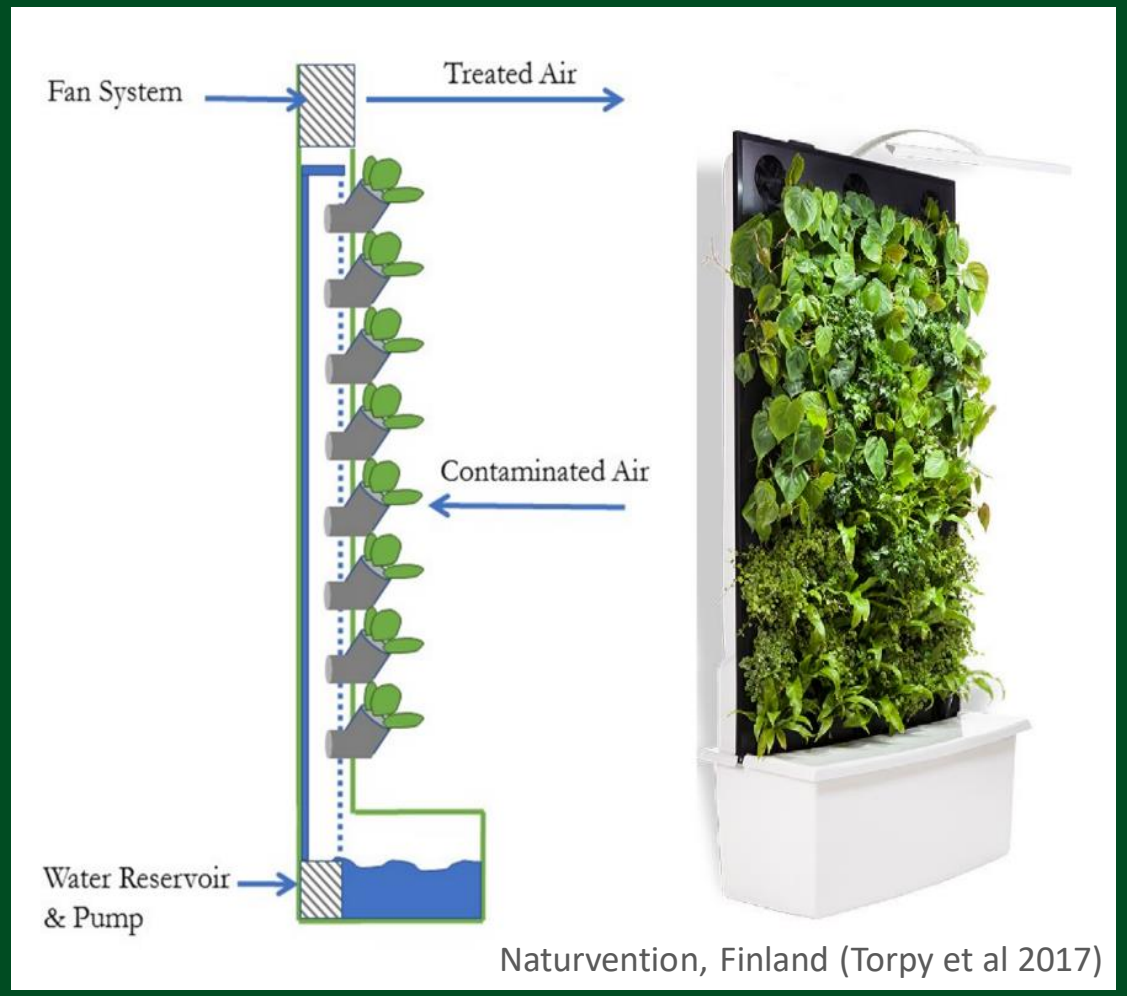
Dominici et al 2021

Active botanical biofiltration



Junglefy, Australia

Mechanical ventilation is used to increase pollutant transfer to substrate and plants



Naturvention, Finland (Torpy et al 2017)

Manly Vale B-Line carpark
Opened 5/12/2018

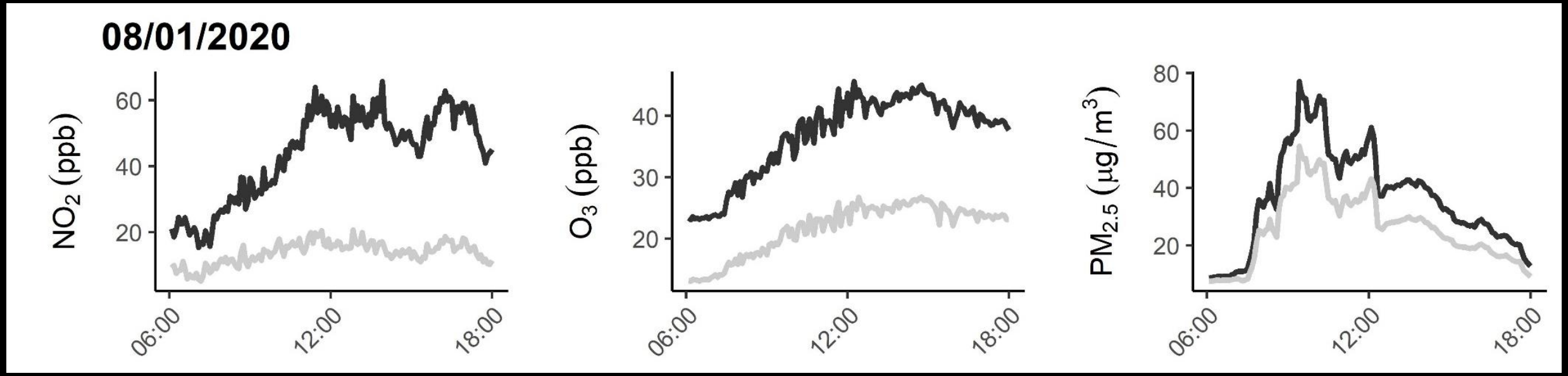
Active phytosystem CADR

Pollutant	Source	CADR ($m^3.h^{-1}.m^{-3}$ of Substrate or m^{-2} biofilter area)
NO_2	Ambient indoor	**88**
NO	Ambient indoor	**52**
O_3	Ambient indoor	**249**
NO_2	Road traffic	**121**
O_3	Road traffic	**50**
$PM_{2.5}$	Road traffic	**40**

Pettit et al 2020, 2021

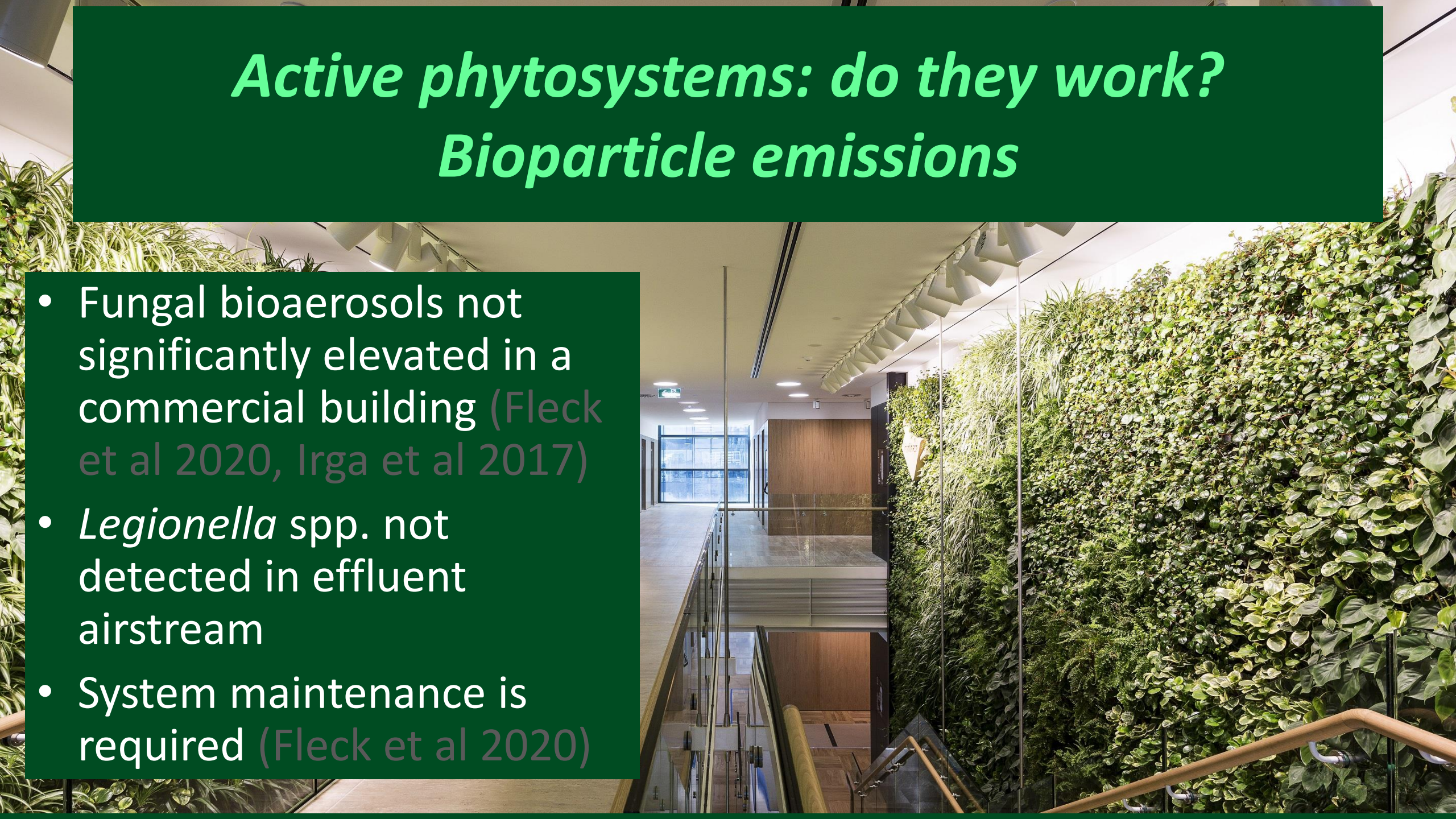

Manly Vale B-Line carpark
Opened 5/12/2018
NSW GOVERNMENT
Transport for NSW
junglefy
Modelled CADRs (m³/h)
$PM_{2.5}$: 8,463
NO_2: 3,050
O_3: 8,361
P
Park & Ride
Parking
No entry

'*Black Summer*' bushfire smoke removal



Pettit et al (2020)

Active phytosystems: do they work? Bioparticle emissions



- Fungal bioaerosols not significantly elevated in a commercial building (Fleck et al 2020, Irga et al 2017)
- *Legionella* spp. not detected in effluent airstream
- System maintenance is required (Fleck et al 2020)

Problems

Gaps

- BVOCs, O_3, SO_x inadequately researched
- COVID 19?
- Effect sizes in ventilated buildings?
- Net zero contribution?

Barriers to implementation

- Space availability in highly urbanized environments
- Perception of ‘Green washing’
- Perception of ROI: Environmental, social, and governance (ESG)

Thank you CASANZ!

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