HOW AND WHY POTTED-PLANTS REALLY DO CLEAN INDOOR AIR
SUMMARY

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1. INTRODUCTION

1.1 Research background

Early pioneering studies on potted-plants and air-pollution reduction were carried out by B.Wolverton in the USA for NASA, and then with the US Interior Plant Growers Assoc (1989-1993). Those studies investigated potential uses of potted-plants in space-stations. It was found they could absorb Volatile Organic Compounds (VOCs)*, a major class of indoor air contaminants. Other overseas studies, on outdoor plants, have shown that their leaves absorb air-borne inorganic pollutants, eg nitrogen oxides or ozone. These lines of research formed a basis for our investigations into plants and indoor air quality.

** (Organic compounds are compounds of carbon - the compounds [carbohydrates, proteins, lipids, etc] which make up all living organisms [hence the name]. The term also refers to the carbon compounds making up 'fossil fuels' – remnants of previous life – coal and petroleum, and their products. Almost all modern interior building and furnishing materials contain, or are composed of, 'plastics', 'synthetics', solvents, glues, paints, etc, made from petroleum derivatives. Hence the prevalence of outgassed vapours of Volatile Organic Compounds in indoor air, eg benzene, toluene, xylene.)*

1.2 Why worry about indoor air quality?

Over 80 % of Australians live in cities, where we spend about 90% of our time indoors. A number of studies have shown that indoor air generally contains higher levels of contaminants than outdoor air - often several times higher concentrations. Over 350 VOCs have been identified in indoor air, and although usually in very low concentrations, they are now recognized as causative agents of 'sick-building syndrome' or 'building-related illness', symptoms including headaches, sore eyes or throat, loss of concentration, nausea & breathing problems. All VOCs are to some extent fat/oil-soluble (ie, lipid-soluble). Thus they tend to dissolve in and disrupt cellular membranes, and hence cell function. Of course, not all indoor environments are hazardous, but, from our latest research, summarized below, it turns out that potted-plants can improve indoor air quality substantially *whenever it is needed – a very clever trick*!

2. OUR PREVIOUS LAB TEST-CHAMBER STUDIES

First, we conducted a number of controlled laboratory test-chamber studies into the capacities of potted-plants to remove air-borne VOCs.

2.1 Experimental set-up

- Four Perspex test chambers (~0.22 m^3)
- Two VOCs - benzene and *n*-hexane, tested separately
- Repeated daily doses (up to 5-10 times Aust. occupational maxima)
- In light and dark
- Then, plant removed, &
- Potting mix tested alone
- Tests on microbial cultures extracted from potting-mix

- Seven internationally used indoor foliage plant varieties, from five species:
    - *Spathiphyllum* 'Petite' (Peace Lily)
    - *Spathiphyllum* 'Sensation' (Peace Lily)
    - *Dracaena deremensis* 'Janet Craig'
    - *Dracaena marginata*
    - *Epipremnum aureum* (Devil's Ivy)
    - *Howea forsteriana* (Kentia Palm)
    - *Schefflera amate* (Qld Umbrella Tree)

2.2 Laboratory Findings

The system worked well:

- Potted-Plant Microcosm (PPM) can eliminate high air-borne concs. of VOC in 24 hr
- PPM improves on exposure to VOC
- Maintains performance with repeated doses indefinitely
- Is equally effective day and night (ie light and dark)
- PPM can also remove very low residual VOC concs, (to ~zero)
- Microorganisms of potting-mix the primary 'rapid response' agents
- *(Plants nourish mircoorganisms in root-zone to improve mineral uptake – symbiosis)
- By biochemical pathways which are 'induced'
- *(Which will metabolise VOCs, to CO_2 and H_2O)
- Identified about 50 bacterial species

(**Known from other research*)

BUT - all this work (ours and others') was done in laboratory test chambers.

- **What about the effectiveness of the PPM in 'real-world'?**
- **Would you need a jungle in every room to do any good?**

A crucial next step was to undertook an 'on-location' study.

3. OFFICE FIELD STUDY

In 2003/2004, we conducted the first controlled, experimental, office field study, in staff offices in three buildings at UTS (two air-conditioned, one not).

3.1 Experimental set-up

- Two investigations, outlined below
- Total of three planting regimes (plus 'controls', ie no plants)
- Over two experimental periods of 5-9 weeks
- Total of 60 office-experimental-units
- 12 offices per treatment
- Portable monitors to sample TVOCs*, temperature, humidity, CO_2, CO.
- Passive vapour monitors to identify individual VOCs.

*(*TVOC = Total Volatile Organic Compounds)*

***Investigation 1*. Floor-specimens - *Dracaena deremensis* 'Janet Craig'**

- Two buildings (one air-conditioned, one not)
- Three treatments: 0, 3, or 6, pots
- Plants – ht 1.3 m, 300 mm pots

***Investigation 2*. Table-specimens - 5 *S.* 'Sweet Chico' + 1 *D.* 'Janet Craig'**

- Two buildings (one air-conditioned, one not)
- Two treatments: 0, or 6 mixed-pots
- Plants ht 30-40 cm, 200 mm pots

3.2 Office Findings

The system works in the real-world.

- **TVOC loads in all blgs ranged from 50-400 ppb (higher than outside)**
- **When TVOCs >100 ppb, levels reduced by ~ 70% (to <100 ppb), with any planting**
- **When TVOC levels were <100 ppb, potted-plants had no effect.**
- **Equally effective in air-conditioned and non-air-conditioned bldgs.**

Which means that

- **TVOC loads of ~100 ppb will kick start the metabolic induction process for VOC removal.**

The results also show that:

- **3 floor-specimens *D.* 'Janet Craig' = 6,**
- **6 mixed table-sized specimens = 3 or 6 floor specimens *D.* 'Janet Craig'**
- **Lower numbers &/or smaller plants might do?**

4. FOLLOW-UP CONTROLLED LAB DOSE-RESPONSE TRIALS

The aim here was to investigate patterns of induction with controlled, increasing concentrations of VOC. We had identified 14 VOCs in office air in all three buildings, with toluene and xylene (components of the 'BTEX' group) in the top five, along with methylbutane and methylbenzenes.

4.1 Experimental set-up

- Toluene and *m*-xylene used as test VOCs.
- Same test chambers as before (see Section 2)
- Same spp. as in offices - *D.* 'Janet Craig' and *S.* 'Sweet Chico',
- Repeated daily doses, and weekly dose increments, for each VOC:
    - 0.20 ppm (200 ppb),
    - 1.0 ppm,
    - 10 ppm
    - 100 ppm.
    - &, same conc. series with mix of both VOCs, (*D.* 'Janet Craig' only)

4.2 Major laboratory findings

- Doses of 0.20 ppm did induce VOC removal response within 1 week
- Further induction occurred at each step of dose increments
- Similar pattern with the mixed doses
- Synergistic interactions found: toluene speeded removal of xylene

The results confirm and strengthen the conclusions of the office field study, ie. that:

The potted-plant microcosm is an effective, self-regulating indoor-air-cleansing system, for the 'bioremediation of indoor air'; or 'phytoremediation of indoor air quality'.

5. REACTIONS OF PARTICIPANTS

Over 40 staff involved. Typical comments at end of the experiments included:

- I wish you would do more projects like this!
- The plants improve the office ambience.
- It has been a pleasure having the enjoyment of these plants.
- They made the room feel fresher and it felt good having the green plants nearby.
- It feels stark and empty now without them!
- I would like to have at least three plants; I wish you would do it more often!
- It's more pleasurable being in a workroom where there is a good proportion of plants – it gives one a lift to one's mood.
- Especially when one comes in on a Monday morning, the room feels fresher!

6. SIGNIFICANCE OF FINDINGS FOR HORTICULTURAL INDUSTRY

Industry can now confidently:

- Market potted-plants to reduce indoor air pollution
- Promote them to complement (sometimes replace?) engineering measures
- Start designing arrangements to 'fit any space'
- Point out that they are self-regulating biofilters –
- They kick into operation whenever TVOCs rise above negligible levels!
- They give an appropriately graded response, so that:
- TVOC loads are reduced to <100 ppb (negligible levels)
- **Emphasise that they are portable, flexible, inexpensive, low-maintenance, and beautiful, while they are improving and maintaining clean air quality**

Useful points to bear in mind:

- The mass of plant materials need not be overwhelming
- They can be scaled up or down for indoor spaces or any size
- Suitable in every type building, eg:
    - Private homes / units
    - Classrooms
    - Hospitals
    - Shopping malls
    - Hotels
    - Commercial buildings
    - Industrial installations
    - Anywhere else you can think of!

6. FUTURE R&D NEEDS

To undertake improvement in the capacity of the potted-plant microcosm for indoor air biofiltration / phytoremediation, investigations are needed on:

- Further field-tests of effectiveness, eg in new buildings & other specific situations

- VOC removal capacities with other:
    - Major VOCs and mixtures
    - Plant species/ varieties
    - Planting regimes
    - Potting mixtures

- Analysis of plant/root-zone-microorganism interactions, eg:
    - Effects of VOCs on plant/rhizosphere signals & communication
    - Microbial population dynamics and physiology

We are now looking for further funding to continue this research program.

Final Report of this study, giving full details of experiments, is now available from Horticulture Australia Ltd.- *Potted-Plants Substantially Improve Office Air Quality* (Burchett et al., 2005)