

PLANT/SOIL CAPACITIES TO REMOVE HARMFUL SUBSTANCES FROM POLLUTED INDOOR AIR

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The aesthetic value of indoor plants is easily seen, however the unseen ability of indoor plants to improve indoor air quality has never been conclusively shown or, until now, quantified.

Research at the University of Technology, Sydney has shown that indoor plants do improve air quality. As a result, clear claims can now be made as to how indoor plants improve air quality, and development of varieties with an even better capacity for improving indoor air can begin.

Why worry about indoor air quality?

Could everyday activities in our homes and offices, places we usually consider to be essentially unpolluted, expose us to the greatest contact with potentially toxic air pollutants?

Could ordinary consumer products such as air fresheners, deodorisers, household pesticides, cleaning compounds and various building furnishings and materials be more of a threat to our health than industrial pollution? The short answer to these questions is yes!

The ongoing development of new materials and products has substantially enhanced our standard of living. In our homes and offices, modern building materials, insulation, glues, fabrics, carpets, cleaning materials, personal care products and pesticides, often expose us to a wide spectrum of chemicals in the air we breathe. The presence of these chemicals, even at very low levels is now known to influence indoor air quality with potentially adverse affects on our health. More than 300 different volatile organic compounds have been identified in office air. Exposure to these pollutants is suspected as the major cause of the headaches, lethargy, sore eyes and

respiratory problems experienced by some office workers. There is an increasing awareness of the costs to our health, the environment and even to productivity.

We tend to take for granted the air we breathe both outdoors and indoors, particularly indoor air if it is “conditioned.” Our perception of air quality is influenced by our sense of smell and to a lesser extent visually. This perception can be misleading; our senses may not be able to detect pollutants in trace amounts that are harmful to our health. When exposed to an odour for a period of time the perception of the odour is diminished as our olfactory cells tire very easily. Our lungs are our most important point of contact with the outside world. We may drink 2 litres of liquid each day but we breathe in approximately 6 to 10 litres of air every minute, around 15,000 litres per day. Most urban dwellers usually spend about 80% or more of the time indoors, so the quality of indoor air becomes a major health consideration.

Plants as decontaminators

Outdoor plants are known to absorb air and soil pollutants and detoxify them. Plants and soil microorganisms are used, for example, in the remediation of contaminated soils. Previous screening studies have shown that some ‘indoor’ plants can also reduce concentrations of air-borne VOCs and suggested that the microorganisms of the soil might also be involved.

We compared the VOC removal performance of three top-selling indoor plant species, *Howea forsteriana* (Kentia palm), *Spathiphyllum wallisii* var. Petite (Peace Lily), and *Dracaena deremensis* var. Janet Craig. Benzene (a carcinogen) and *n*-hexane (a neurotoxin) were chosen as the test VOCs, because they are common in indoor air.

Findings

Overall all three species were found to be effective removers of both VOCs. There were strong similarities in response among the plant species and with both VOCs, although differences between species were also found (Figs 1-2).

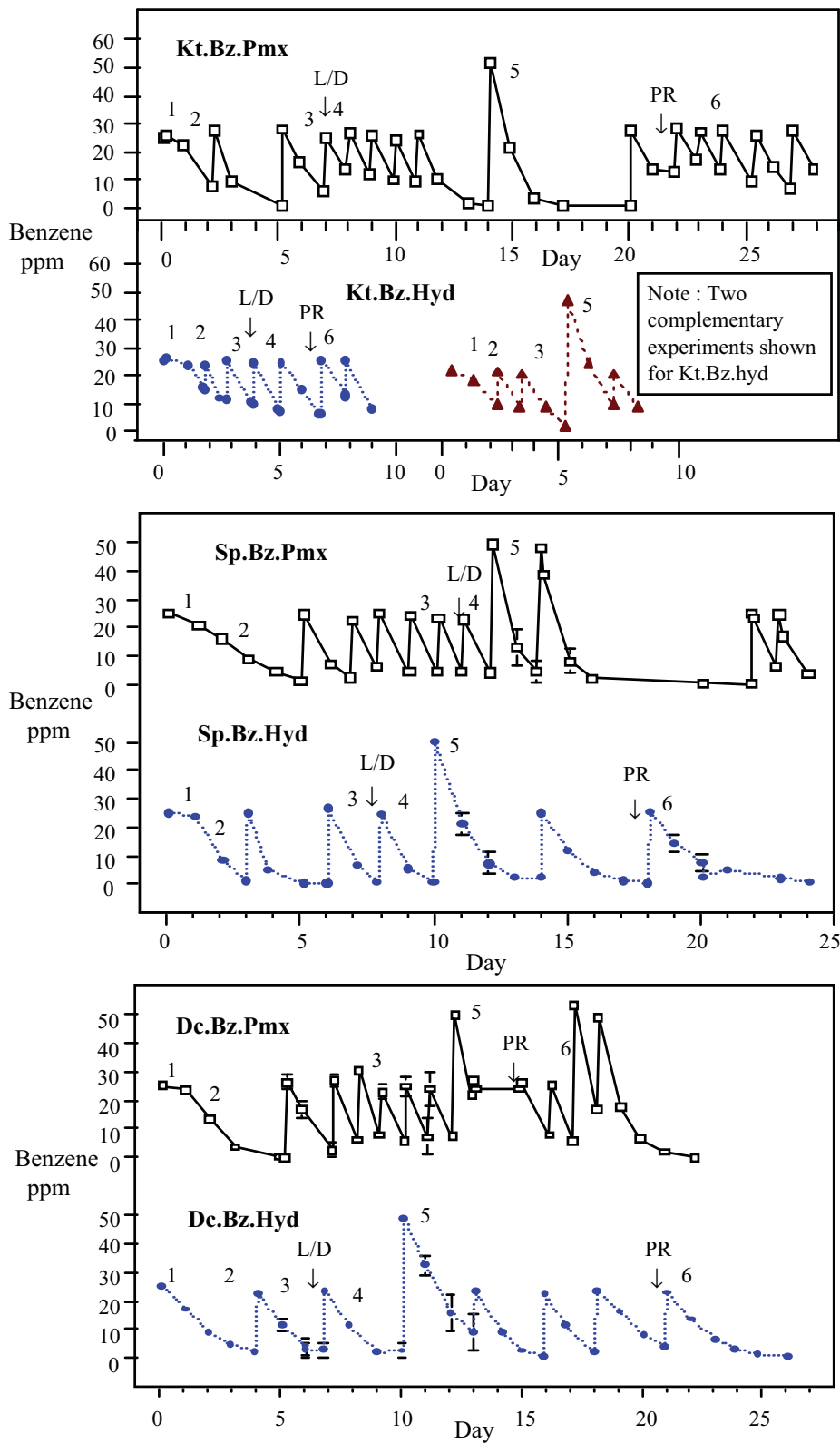


Fig.1. Benzene (Bz) levels in test chambers during experiments with three indoor plant species.

Step increments in VOC concentration correspond to injections of benzene Kt = Kentia (Howea forsteriana); Sp = Spathiphyllum var, Petite; Dc = Dracaena deremensis; Pmx = potting mix; Hyd = hydroponics; L/D = change from light to dark; PR = plant removed and used substrate or medium returned to chamber. Each point mean \pm SEM (n = 4).

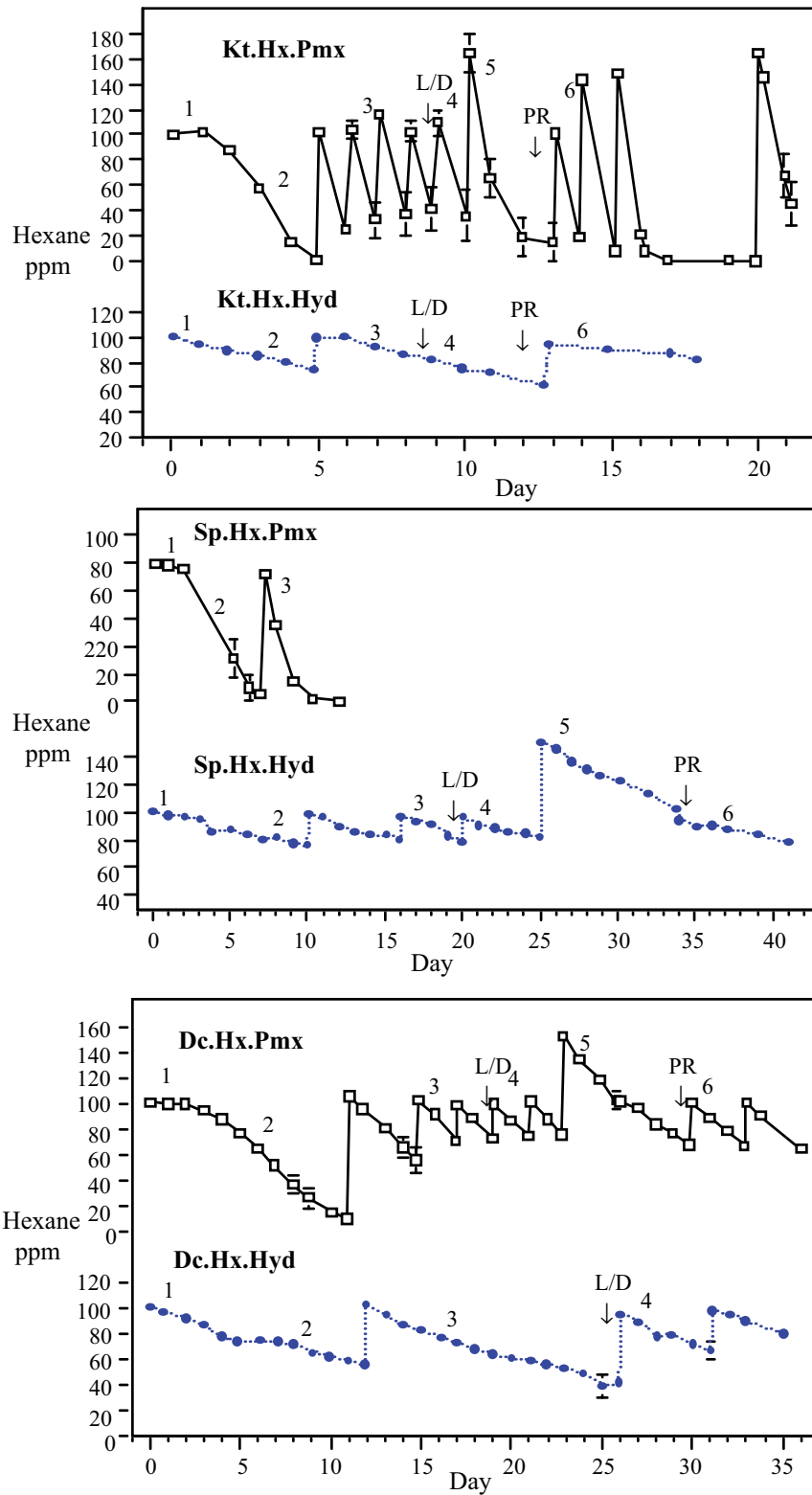


Fig.2. *n*-hexane (Hx) levels in test chambers during experiments with three indoor plant species. Step increments in VOC concentration correspond to injections of *n*-hexane. Kt = Kentia (*Howea forsteriana*); Sp = *Spathiphyllum* var., Petite; Dc = *Dracaena deremensis*; Pmx = potting mix.

We then tested three other widely used species, *Epipremnum aureum* (Devil's Ivy), *Schefflera* 'Amate' (Queensland umbrella tree) and *Spathiphyllum* 'Sensation' with similar results.

Like most research projects, the findings unfolded like a detective story – following clues and piecing together the evidence.

What happens with the first dose of VOC?

Since we had to start somewhere, each experiment was commenced in continuous light, such as can be found in offices, hotels or shopping malls. Immediately after applying the first dose of VOC the removal rates were very slow. However, within a fairly short time (1-2 days for benzene; 4-5 days for *n*-hexane) they accelerated markedly. This increase in rate was in response to a 'taste' of the VOC. It involves the 'switching on' (ie induction) of a biochemical system to deal with the compound (consume / metabolise it). With further topping-up doses with either VOC this induced removal activity was maintained, or even increased further. That is, they get better with practice!

Is light necessary for VOC removal?

To test this question, plants were then transferred to continuous dark (lights off, black plastic over chambers). It is well known that under these conditions plant photosynthesis stops, so metabolic activity will be largely reduced to baseline 'dark' respiration. Stomates will also be shut, so there will be virtually no gaseous absorption into the leaves. What happens now? Does VOC removal slow down? No! The process kept on going at the same sorts of rates as in the light (Figs 1-2). In addition, when (still in the dark), new doses of VOC were injected, at even higher concentrations, (ie raised from 25 to 50 ppm for benzene and from 100 to 150 ppm for *n*-hexane), the removal rates usually increased further as well. This indicates that with each plant species, the system remained fully operative under dark conditions, and in fact could respond to, and cope with, higher doses of each compound. In other words, we had not yet arrived at concentrations high enough to saturate the biochemical removal system (and that aspect still remains to be investigated further).

What are the relative roles of the plant and soil micro-organisms, in the removal process?

Was it the plant itself that was directly responsible for the VOC removal, even in the dark? To answer this, we removed the plants, replaced the potting mix into the pots, and put the pots back into the chambers. New standard doses of the VOC were then applied. Again, the VOC continued to disappear at rates comparable with, though generally slightly less than, those found prior to the plant's removal (Figs 1-2). After the plant's removal, experiments were sometimes continued for a further 7 - 10 days, with top-up doses as required, and the activity was maintained in every case.

The sustained activity with further doses, and in the absence of the plant, tells us two things: First, the continued activity confirms that this is a true biological response, and not merely an adsorption / absorption process. Secondly, it shows that it must be the micro-organisms of the potting mix that are the 'rapid-removal agents' of the pot-plant system. The plant is somehow involved, however, as discussed below.

What happens when the plant is transferred to hydroponics?

This was to test the plant removed from the potting mix. The roots were thoroughly washed in sterile water to remove particles of the potting mix and if possible some of the micro-organisms clinging to the surface of the roots. Nevertheless, some VOC removal sometimes continued to occur in hydroponic medium (Figs.1-2). Sometimes, though not always, the system achieved the same removal rates as in the potting mix. This suggests that the microorganisms are at least in some cases fairly firmly attached onto or inside the roots. The differences in response among the plant species in this medium suggest different relationships between the plant and the microorganisms associated with the root systems.

What happens when unplanted potting mix is dosed with VOC?

Tests with watered new potting mix, that had not been used to grow plants, showed a very slow induction when dosed with VOC, and the final induced activity was estimated to be only about half of that with plants (Fig. 3). In addition, there was some evidence of the system becoming exhausted. The results confirm what is known of potting mixes generally, namely that they contain a supply of microorganisms before plants are introduced. However, the results also suggest that the readily available nutrients for microbial growth and reproduction in the potting mix will not last very long in the absence of a growing plant.

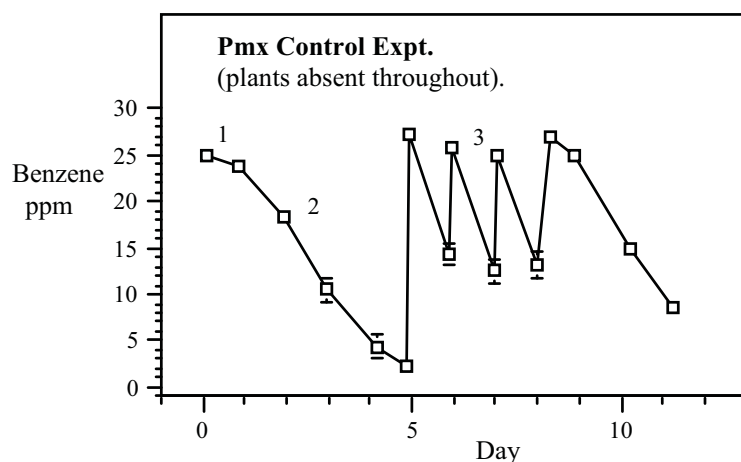


Fig.3. Benzene (Bz) levels in test chamber during control experiment with "virgin" potting mix, ie. potting mix which not previously used as substrate for plants. Each point mean \pm SEM (n = 4).

The bottom line – a new and improved marketing message

Indoor pot plants can now be confidently promoted as helping to improve the quality of the indoor environment. The way of the future will certainly be to use them routinely for that purpose, and to ensure that buildings are designed to exploit their

usefulness for clean air as well as for their living beauty! In summary, we can safely state that:

1. The pot-plant system really does remove VOCs from indoor air!
2. The system gets better on exposure to VOCs and maintains performance with repeated doses.
3. From 3 to 10 times the maximum permitted Australian occupational indoor air concentrations of each compound can be removed within about 24 hours, under light or dark conditions without saturating the system.
4. The pot plant system can also remove very low residual concentrations as well,
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 - The fact that similar responses were found with the three plant species, under all of the test conditions, indicates two things: (a), that this is a general plant-soil phenomenon, that is, it can be expected to be found with any pot-plant species; and (b) that it is the micro-organisms of the growth medium which play a primary role as the 'rapid-response agents' in VOC removal in the potted-plant system.
 - The plants are also involved. Comparisons of performance among the three plant species indicate that they have different substrate microbiological populations, and / or that there are different relationships between the microorganisms and the roots of the particular species. The results with new potting mix also indicate the nourishing role of the plant in promoting microbial growth.

It is well established from research with crop species that different plant species develop a species-specific soil flora around their roots, producing a symbiotic microcosm of activity. It is also known that plants expend energy nourishing their substrate microorganisms, sometimes secreting from 25 to 45% of their net photosynthetic product from their roots to keep the microbes growing.

Further work

We are now working on two follow-up projects. The first is an investigation into which microorganisms, associated with these plant species and growth media, are involved in the VOC removal process. This will enable the horticultural development of plant-and-soil varieties and systems with enhanced clean-air capabilities. The second project is on the testing of these and other interior foliage plant species under flow-through conditions, to seek answers crucial questions about how much plant material, of which species will make the most impact on improving indoor air quality in the 'real world'. For this project we will be using both test chambers of the same size as those used in the static experiments, and a scaled-up, room-sized dynamic chamber, in collaboration with associate investigator Dr. Steven Brown, at the Air Quality Laboratory of CSIRO, Melbourne.

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