STUDY OF ABSORPTION OF VOC'S BY COMMONLY USED INDOOR PLANTS

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ABSTRACT

This study is part of an investigation of the decontamination capabilities of indoor plants. Three internationally used species, *Howea forsteriana* Becc. (Kentia Palm), *Dracaena deremensis* Eng. Janet Craig, and *Spathiphyllum* Petite (Peace Lily), were evaluated for the ability to reduce or remove benzene and n-hexane from indoor air. Plants tested in both potting media and hydroponic conditions removed the individual VOC's at concentrations equal to 2 and 5 times the maximum occupational exposure levels recommended by the Worksafe Australia Time-weighted average exposure standard (TWA), [1]. The process initially took from 2-5 days, after which rates increased so that removal was achieved thereafter in 24 hours. This is typical of an enzyme induction response. The plant and potting media create a soil/plant microcosm in which normal soil microflora, possibly triggered by chemical signals from the plant, play a major role in the breakdown of volatile chemicals and hence improve indoor air quality.

INTRODUCTION

It is well established that plants have the ability to absorb toxic compounds from the environment and detoxify them [,2,3,4,5]. Our own work [6] has shown that *Howea forsteriana* (Kentia Palm), an internationally used indoor palm has the capacity to remove several times the maximum occupational exposure levels of benzene and n-hexane in indoor air in static chamber tests, and its capacity to do so is increased by exposure. Similar findings have been made with two other internationally used indoor plants *Dracaena deremensis* Janet Craig, and *Spathiphyllum* Petite (Peace Lily), using the experimental protocols and methods described in [6].

RESULTS AND DISCUSSION

Our results have shown that reduction of VOC concentration was due to sustained biological processes, rather than simple adsorption processes, and that an "induction period" is apparent, (figures 1,2,3). VOC removal continued once induced, independent of light, both with plants maintained in potting media or in hydroponic conditions, suggesting that root and/or soil bacteria (in potting media), or bacteria closely associated with the roots (in the hydroponic case), play a major role in the detoxification process. It appears that the plant and soil microorganisms may have complementary roles in this process.

Rhizosphere microorganisms

Microorganisms are capable of an enormous range of metabolic activity, and their enzymes are generally specific for individual compounds [7]. They hence have the capacity for enzyme induction for the metabolism of a wide range of foreign compounds, both those that can be regarded as normal food sources, as well as many xenobiotics. It has been proposed [8], that root border cells, which are healthy somatic cells released daily from root tips into the rhizosphere in response to endogenous and environmental signals, control the ecology of the rhizosphere by the programmed release of biologically active chemicals that regulate growth and gene expression in microbial populations. As a result plants can thrive in soil contaminated to levels that are often orders of magnitude higher than current regulator

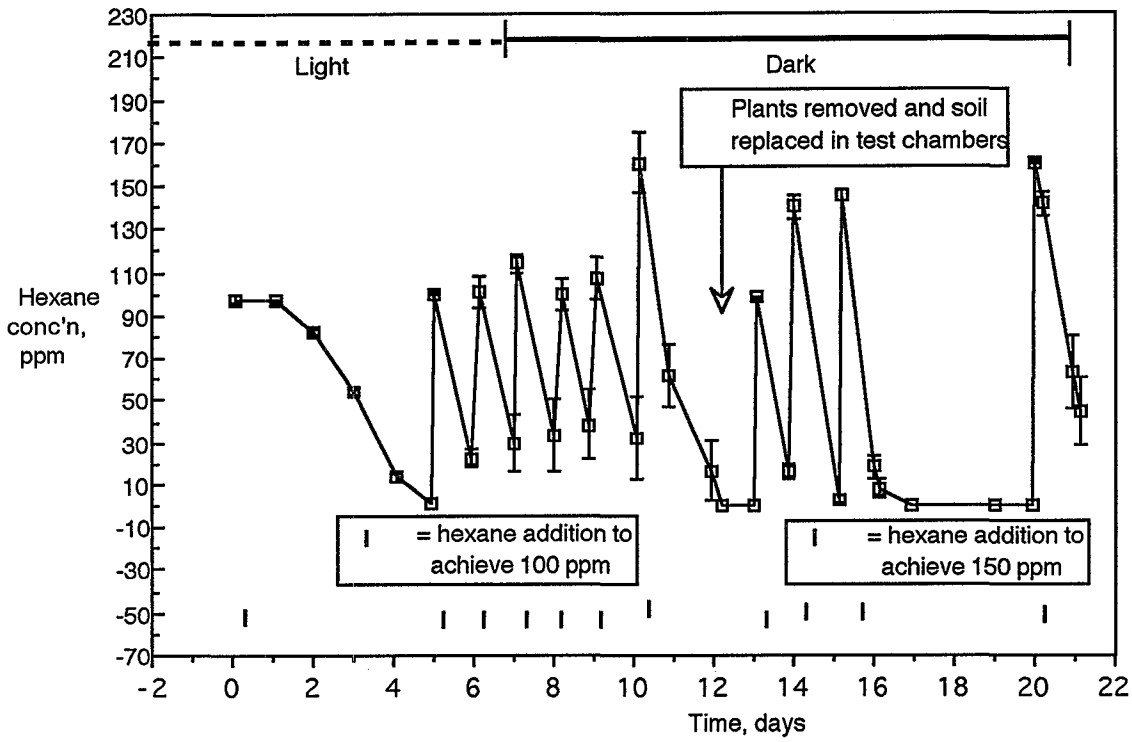

Fig.1. Hexane levels in test chambers containing Howea forsteriana (Kentia palm)
Each point is the mean of 4 experiments (Mean ± SEM).

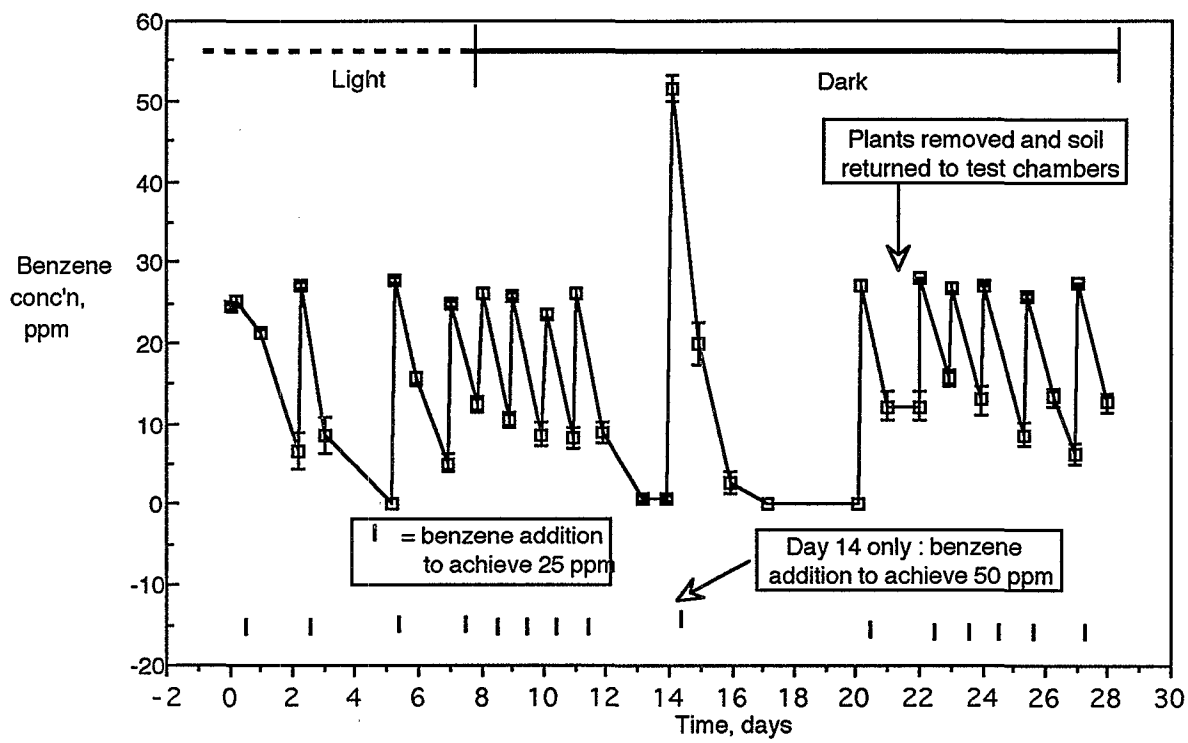

Fig.2. Benzene levels in test chambers containing Howea forsteriana (Kentia palm).
Each point is the mean of 4 experiments (Mean ± SEM).

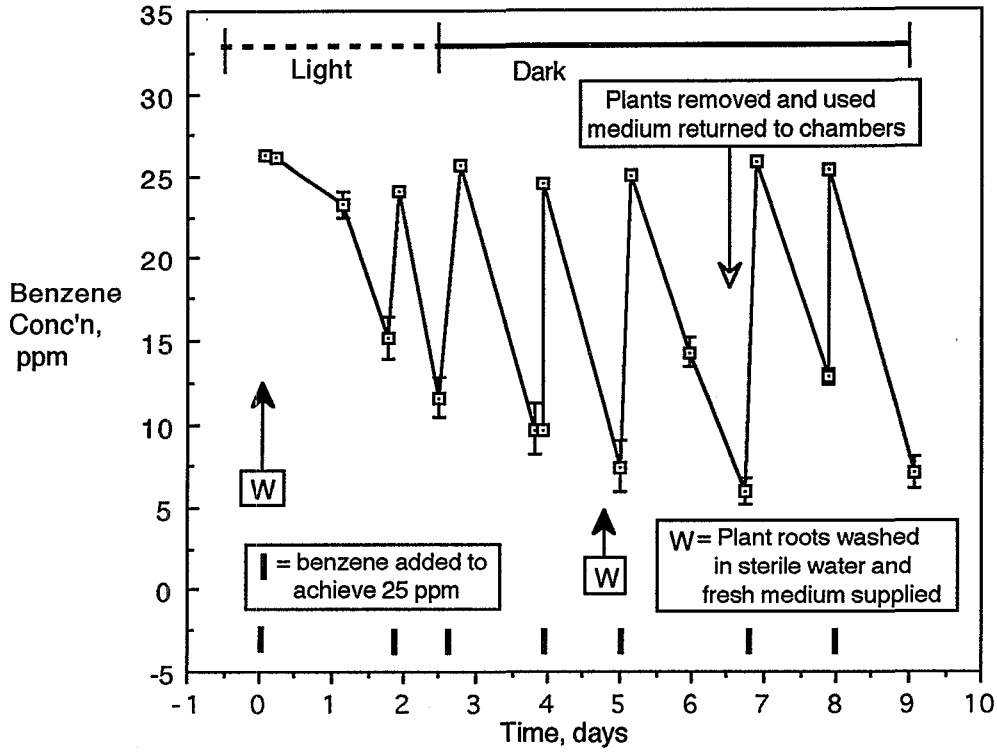

Fig.3. Benzene levels in test chambers containing Howea forsteriana (Kentia palm) : Bare plants under hydroponic conditions. Each point is the mean of 4 experiments (Mean ± SEM).

limits. These limits are set from a human health view point, and are independent of plant tolerance limits [9].

Plant metabolism

Plants generally detoxify, rather than fully metabolise xenobiotics. The role of transport and detoxifying reactions in the processing of xenobiotics is slowly being elucidated, although it was shown in the 1940s that various xenobiotics such as chlorohydrin, chloralhydrate and 2-chlorophenol were infused into intact plants, or taken up from the gas phase, and were metabolised to b-D-glucosides and b-D-gentiobiosides. These metabolic products were isolated and identified as crystallized derivatives, and amounted to several grams per litre of plant extract [10]. The detoxification processes for foreign chemicals by plant enzymes show numerous similarities with xenobiotic metabolism in the mammalian liver [10]. The inducibility of metabolic plant isoenzymes has been shown to proceed for plant cytochromes P 450, which function in much the same way as mammalian liver cytochrome P 450 systems [10]. Jakoby and Ziegler [7], suggest that a range of enzymes with exceptionally broad specificity participate in detoxifying foreign compounds, discriminating between foreign and physiologically essential soft nucleophiles, although how they do so is unknown. Plants use internal cell storage with a following complex network of processing reactions leading to soil transformation of plant residues [10].

Removal rates

Mr. Stephen Brown of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Building, Construction and Engineering has analysed some of our preliminary data on the effectiveness of Kentia palm in removing VOCs [5] from air under static conditions in sealed chambers. This was done as part of a proposed joint study to

evaluate the significance of the static results in a more realistic environment, ie., a dynamically ventilated test room (33.6m^3) which will allow better simulation of conditions in real buildings. He estimated that the VOC removal rates presented in that paper [6], correspond, in the dynamic situation, to approximately 0.03 to 0.06 air changes/h/plant (ACH/plant). Office buildings have ventilation rates ranging from about 0.5 ACH to about 2 ACH.
He concluded that, for this plant to effect VOC removal rates equivalent to that recommended by the American Society of Heating, Refrigerating Air Conditioning Engineers (ASHRAE Standard 62), the equivalent of 8 large specimens (in 300mm. pots) per room of 35m^3 would have to be used. Alternatively, if the lower ASHRAE ventilation rate of 0.35 ACH is used as the basis for calculation, a reduction of VOC pollutant level up to 20% per h with that number of plants may be possible. Brown suggested: i) there may be more effective plants, or that more effective plants could be produced, ii) performance at the typical indoor air concentrations (generally 100 - 1000 times lower than those used in these experiments) may be better. In addition, we know that we do not yet understand the mechanisms properly. Brown commented "I don't believe plants will be the panacea to control of indoor air pollutants (source control is always going to be optimum), but if they can help I don't see why we shouldn't optimise their effect; people are going to use them indoors, and they can presumably be made more effective" (pers. comm.). We are at present setting up experiments to determine the relationships between effectiveness in absorption and plant size in each species, as well as characterising the soil micro-organisms involved.

Further studies

The results so far indicate a likely universality of capacity of commonly used indoor plant-and-soil combinations, once induced, to remove both relatively high and very low concentrations of VOCs, in static chambers. Differential rates of removal of the VOCs, and species differences in rates of removal and how these relate to the sizes of shoots, leaves and root system are the focus of our future investigations. These will also include work directed towards elucidating the specific composition of the microbial community associated with each plant species.

Genetic enhancement of phytoremediation

A growing knowledge of the factors important to phytoremediation of contaminated soils is likely to assist the present work with VOCs, by providing a basis for genetic modification for enhanced performance. Based on what plants can absorb, sequester, destroy and tolerate, these traits can be specifically targeted by traditional breeding as well as molecular biology [11].

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REFERENCES
1. National Occupational Health and Safety Commission, 1991. Exposure standards for atmospheric contaminants in the occupational environment, AGPS, Canberra, Australia
2. Sandermann, H. 1992. Plant Metabolism of Xenobiotics. *TIBS* 17, 82-84.
3. Foyer, C.H., Descourvieres, P. and Kunert, K.J. 1994. Protection against oxygen radicals: an important defence mechanism studied in transgenic plants. *Plant, Cell and Environment* 17, 507-523.
4. Schulte-Hostede, S., Darrall, N.M.. Blank, L.W. and Wellburn, A.R. (eds.) 1987. *Air Pollution and Plant Metabolism,* Elsevier, NY.
5. Taylor, G.E., Pitelka, L.F., and Clegg, M.T., (eds.) 1991. *Ecological Genetics and Air Pollution,* Springer Verlag, NY.

6. Wood, R.A., Orwell, R.L. and Burchett, M.D., 1997. Rates of Absorption of VOCs By Commonly Used Indoor Plants. *Proceedings of 5th International Conference on Healthy Buildings/IAQ '97, Global Issues and Regional Solutions.* Vol. 2, 59-64.
7. Jakoby, W.B. and Ziegler, D.M., 1990. The Enzymes of Detoxification. *The Journal of Biological Chemistry,* Vol.265, No34.5, 20715-20718.
8. Zhu, Y., Pierson, L.S. and Hawes, M.C. 1997. Induction of Microbial Genes for Pathogenesis and Symbiosis by Chemicals from Root Border Cells. *Plant Physiol.* 115: 1691-1698.
9. Cunningham, S.D. and Ow, D.W. 1996. Promises and Prospects of Phytoremediation. *Plant Physiol.* 110: 715-719.
10. Miller, L.P. 1940. Induced formation of Beta-gentiobiosides in gladiolus corms and tomato plants treated with chemicals. *Science*: 92. 2376-2377.
11. Sandermann, Jr. H., 1994 Higher plant metabolism of xenobiotics: the 'green liver' concept. *Pharmacogenetics* 4. 225-241.

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