Capacity of Indoor Plants to Improve Indoor Environmental Quality - A Review

Margaret BURCHETT
UTS, Westbourne, St. Gore Hill, NSW 2065, Australia
Email: Margaret.Burchett@uts.edu.au

Abstract

The developed world is becoming increasingly urbanised. More city-dwellers are living in high-rise apartments, and working in "tower blocks" with air conditioning, generally spending about 90% of their time indoors. The quality of the indoor environment is therefore a major health consideration. Here indoor potted-plants have a special place in environmental improvement, aesthetically, psychologically, and, as now realised, physicochemically as well. Some recent evidence of the multiple benefits of indoor plants to health and well-being is reviewed here. Some of the information was presented at the *International Plants for People Symposium (IPPS)*, held in Amsterdam as part of the Netherlands' Floriade, June, 2002. Together, the results indicate that at home, school, work, or in hospital, indoor plants can improve health, well-being and mental function. Improved health, satisfaction and productivity mean economic benefits for society as a whole. Research now needs to be targeted towards ways in which their capacities to improve the indoor environment can be further enhanced. Better planning and management strategies can then be devised to maximise the benefits of "plants to share our living-space".

Keywords: Indoor plants, aesthetics, psychological benefits, volatiles, air pollution reduction

Introduction

In both Eastern and Western traditions, the aesthetic or spiritual values of plants, encountered in wilderness or parkland, in religious precincts or private gardens, have been recognised for several millennia. The benefits of plants and planted landscapes on the well-being of the human psyche are referred to in literature, and reflected in art and artifacts (see, e.g., Ulrich and Parsons, 1992; Matsuo, 1999; Sim, 1999). The history of the use of plants to beautify the indoor environment is more recent, but in Europe it developed greatly from the early years of the sixteenth century, spurred on by the exploration and exploitation of the edible and other botanical resources of the Americas and Asia. The advancing technology of glass for building conservatories and sun-rooms also increased the popularity of plants indoors.

The developed world is becoming ever more urbanised. In Australia, for example, 80% of our population of 19 million lives in cities, (indeed, about half of us lives in just three of the cities). Around the world, more city-dwellers are living in high-rise apartments, and working in glass-and-concrete "tower blocks", with air conditioning, or at least heating systems. In addition, city-dwellers generally spend about 90% of their time indoors, so that the quality of the indoor environment has become a major health consideration (Abbritti and Muzi, 1995; Krzyzanowski, 1999; American Lung Assoc., 2001). The "outside world" can seem a long way away, and visiting a wilderness area requires a weekend excursion! Under these circumstances, indoor potted-plants have a special place, aesthetically and psychologically. For many city-dwellers, growing indoor, window-ledge, or balcony potted-plants is the only gardening activity available. Fortunately, "indoor gardening" can be done by everyone, regardless of age or health status (which is not always true for outdoor gardening).

Some recent evidence of the benefits of indoor plants to health and well-being is reviewed here. Some of this information was presented at the *International Plants for People Symposium (IPPS)*, held in Amsterdam, as part of the Netherlands' Floriade, 2002, as an update on work in this field.

Psychosocial benefits of indoor plants

The use of indoor plants has been reviewed over the last decade (e.g., Hammer and Wood, 1999). A number of authors consider that our feelings for plants arise from a biological need to relate to natural elements, and that, therefore, when we move to a predominantly indoor existence, we naturally attempt to bring plants with us; that is, the need to have plants near us lies deep within us, deriving from our primate ancestry (Kaplan and Kaplan, 1982, 1989; Kellert and Wilson, 1993; Lewis, 1996).

A number of studies have found that viewing plants and planted landscapes (or even pictures thereof) can reduce stress

Received ; 20 May 2003.

and promote comfort in hospital patients and their families (Ulrich, 1999; Whitehouse *et al.*, 2001). Measures used in various studies have included progress reports from patients or staff on comfort levels and satisfaction with care provided, as well as on clinical parameters such as length of stay, use of pain-killers, or blood pressure levels. In a paper presented at the IPPS, Amsterdam, 2002, Prof. Roger Ulrich, USA, reported that his more recent work had shown that viewing plantings which specifically presented "verdant foliage and flowers", either indoors or through a window, helped calm and ameliorate stress, whereas the presence of hard surfaces, concrete paths, etc., increased stress, in patients and families. The findings also suggest that indoor plants and planted window views would help decrease the stresses caused by the hard-surfaces and barren walls prevailing in buildings generally, particularly in offices and other commercial settings, where furniture and fittings are likely to be utilitarian rather than welcoming and beautiful.

Physicochemical benefits of indoor plants

Over the last two decades indoor plants have also been shown to improve the physicochemical quality of indoor air, which again is crucial to the well-being of building occupants.

Using plants and sun At the IPPS, NL, 2002, Prof Dieter Schempp, an architect from Germany, presented a paper on "green-solar architecture" of which he is a pioneer. The design involves the incorporation of a greenhouse, conservatory or plant-solarium component, which, receiving solar energy, provides a "green-plant-based" air conditioning system. The photosynthesis removes carbon dioxide and restores the oxygen content for the building as a whole. The positioning of the solarium enables maximum benefit from the sun for powering temperature control in the building as well. Care has to be taken with plantings to ensure optimal growth and maintenance, and hence performance of the system. The concept also, of course, involves the installation of appropriate watering and drainage lines, humidity sensors and other control devices. Schempp summed up the usefulness of the concept thus: "it is a symbiosis of nature and technology... it [is] also cost-effective and future oriented, with growing acceptance and increasing commercialisation – and it is beautiful". From our own and other studies, it can also be concluded that such plants, together with their growth media, would be reducing pollution levels in the indoor air of the building as well.

Potted-plant indoor air pollution reduction City air is always polluted, mainly from motor vehicles, and further chemicals are added by indoor activities. Over three hundred volatile organic compounds (VOCs) have been found in indoor air, and the mixtures are considered to be a major cause of "building-related illness", particularly in air-conditioned buildings (Carpenter, 1998; Brasche *et al.*, 1999; Carrer *et al.*, 1999). Symptoms include headache, respiratory problems and loss of concentration (Wolkoff, 1995; Weschler and Shields, 1997). A number of studies in the1990s showed that indoor potted-plants could reduce VOC levels, as well as dust and other air-borne pollutants (Wolverton Env. Serv., 1991; Wolverton and Wolverton, 1993; Lohr and Pearson-Mims, 1996; Coward *et al.*, 1996). The Wolvertons (1993) suggested that microorganisms of the growth medium might also be involved in the removal of the air-borne VOCs.

Our own studies have confirmed and extended the findings of the earlier studies, and thrown light on the dynamics and mechanisms of the process (Tarran *et al.*, 2002; Wood *et al.*, 2002 a,b; Orwell *et al.*, 2003). We have to date tested seven "international" indoor potted-plant species using benzene as the model VOC, with three of the species also being tested with *n*-hexane. Our results showed that the potted-plant, i.e., plant-growth-medium microcosm, is capable of reducing or eliminating relatively high (and very low) indoor air concentrations of the two model VOCs. We also found that normal root-zone microorganisms of the potting mix played a major role as primary 'rapid response' agents in the removal. Rates of removal increased further after initial exposure to the chemical. That is, there was apparently an induction of one or more biochemical pathways, in potting mix microorganisms and in some cases also in the plant. Different potted-plant species showed different efficiencies of removal with the different VOCs, indicating that there were different plant-growth-medium interactions among the species. These findings demonstrate an innate capacitiy in the potted-plant system to help cleanse indoor air, and thus the findings lay the foundation for the development of plant/growth-media microcosms with enhanced VOC removal abilities. Plants are increasingly being used as an interior biofiltration system (Darlington *et al.*, 2000), but further research is needed to develop the "indoor phytoremediation system" for greater effectiveness.

Effects of indoor plants on wellbeing and productivity in workplace and school

A study of the effects on well-being and productivity of "indoor greenery" (potted-plants) in office workers in the Netherlands, by Van Dortmont and Bergs, was reported by Dr Bergs at IPPS, 2002. Using comparable floors of an office building, staff on one floor were provided with plants at their desks, while the control group on the other floor had no plants (total, 250 people). Before and after measurements were made via questionnaires. It was found that the group with plants had a more positive attitude to the working environment (less depressed/stressed), and showed improved concentration, compared with the control group. The improvement in

attitude with plants was most marked among those who worked at computers for more than 4 hours per day. This finding is in line with those of Lohr *et al.* (1996), who found that blood pressure was lowered and reaction time reduced (concentration increased) in students subjected to a computer-based test, when plants were present in the computer laboratory.

Dr Tove Fjeld (IPPS, 2002) outlined four studies from Norway on these issues. In the first study, workers had two test periods, with and without potted-plants in their offices, during 3 months of spring in two successive years, during which they responded to a questionnaire concerning their feelings on health or discomfort. With plants present, there was a 23% reduction in complaints about dry, hoarse throats or itchy skin, and a 30-37% reduction in complaints about coughing, fatigue or stuffy noses. A follow-up study in another office building showed similar responses.

A third study by Dr Fjeld was conducted in the film-viewing room of the radiology department of a hospital, which had no windows or natural light, and which was regarded by its staff as confined and stark. The area was about 80 m^2, and 23 units/containers of common indoor plants, small and large, were placed about the room, on the floor, on desks, around the film viewing screens etc., and extra, full-spectrum, lighting was installed to aid plant health. The result was a 20-35% reduction in complaints about headache, fatigue, "heavy head", dry throat or skin, the largest decreases being in those who spent all or most of their time in the area (as compared with those who spent 50% or less of their time in this area). There was also a drop in absences due to illness ("sick leave") from 15% to 5-6%; i. e., a 60% decrease in such absences. A follow-up study about one year later showed that the decreased absences were still being maintained. This is a dramatic increase in productivity in that department of the hospital.

A similar project was also conducted in six school classrooms, provided with a bank of plants along one wall, compared with six control classrooms without added plants and growth-lights. Questionnaires were completed by the teachers and pupils involved. Teachers reported improved concentration among pupils in classrooms with plants, a 10% drop in complaints about discomfort, and a significant reduction in absences for illness among the children. Total VOCs (TVOCs) in the classrooms with plants were also found to have dropped by 35%.

Dr Fjeld pointed out that the results did not attempt to distinguish whether the positive effects of plants in the work/school environment were the result of a reduction in TVOCs brought about by the plants; the improved aesthetics and living-softness of the work/school environment; better lighting, which would no doubt assist people as well as the plants; or a generalized feeling of being better cared for because someone had taken the trouble to provide plants (the "Hawthorne effect" – positive response to the extra care). The positive effects of plants, however, seem clearly demonstrated by these various studies. The questions Dr Fjeld raised remain good material for research, however, and some are at present under investigation in our laboratory.

In an increasingly urbanized world, the potential for indoor plants to improve the lives of building occupants is an increasingly important matter. At home, at school, or in hospital, the results to date clearly suggest that indoor plants can improve health, well-being and mental function. In the workplace, indoor plants appear to reduce staff stress and improve well-being, satisfaction and attention, and hence productivity, i.e., yield economic benefits (what Wall St. marketeers would call a "win-win situation"). More work is required to improve our understanding of the potential and the means by which plants can improve the indoor environment, so that we can then increase their capacity to improve the physicochemical parameters of indoor air. Better planning and management strategies can then be devised to maximise the benefits of "plants to share our living-space".

Acknowledgemts

Our Group thank the Nursery Industry Association of NSW, the Flower Council of Holland and Horticulture Australia, for funding support for our studies on potted-plants for improved indoor environmental quality.

References

Abbritti, M.C. and G. Muz. 1995. Indoor air quality and health effects in office buildings. Proceedings of Healthy Buildings '95, An International Conference on Healthy Buildings in a Mild Climate (University of Milano and International Centre for Pesticide Safety, Milano, Italy) Vol. 1:185-195.

American Lung Association. 2001 . When You Can't Breathe, Nothing Else Matters. Air Quality. www.lungusa.org/air/.

Brasche, S., M. Bullinger, H. Gebhardt, V. Herzog, P. Hornung, B. Kruppa, E. Meyer, M. Morfield, R. W. Schwab, S. Mackensen, A. Winkens and W. Bischof. 1999. Factors determining different symptom patterns of sick building syndrome - results from a multivariate analysis. Proceedings of Indoor Air '99, the 8th International Conference on Indoor Air Quality and Climate (Edinburgh, Scotland) Vol. 5:402-407.

Carpenter, D. 1998. Human health effects of environmental pollutants: New insights. Environmental Monitoring and Assessment 53:245-258.

Carrer, P., D. Alcini, D. Cavallo, F. Visigalli, D. Bollini and M. Maroni. 1999. Home and workplace complaints

and symptoms in office workers and correlation with indoor air pollution. Proceedings of the 8th International Conference on Indoor Air Quality And Climate (Edinburgh, Scotland) Vol. 1:129-134.

Coward, M., D. Ross, S. Cowards, S. Cayless and G. Raw. 1996. Pilot Study to Assess the Impact of Green Plants on NO2 Levels in Homes. Building Research Establishment Note N154/96, Watford, UK.

Darlington, A., M. Chan, D. Malloch, C. Pilger and M. Dixon. 2000. The biofiltration of indoor air: implications for air quality. Indoor Air 10: 39-46.

Fjeld, T. 2002. The effects of plants and artificial day-light on the well-being and health of office workers, school children and health-care personnel. Proceedings of International Plants for People Symposium. Amsterdam, NL.

Hammer, N. and R. Wood. 1999. Interior Landscapes; An American Design Portfolio of Green Environments. Rockport Publishers, Massachusetts, USA.

Kaplan, R. and S. Kaplan. 1982. Humanscape: Environments for People. Ulrich's Books, Ann Arbor Michigan.

Kaplan, R. and S. Kaplan. 1989. The Experience of Nature; a Psychological Perspective. Cambridge University Press.

Kellert, S. and E.O. Wilson (eds.). 1993. The Biophilia Hypothesis. Island Press, Washington, DC.

Krzyanowski, M. 1999. Strategic approaches to indoor air policy making. Proceedings of the 8th International Conference on Indoor Air Quality and Climate (Edinburgh, Scotland). pp. 230-232.

Lewis, C.A. 1996. Green Nature /Human Nature. University of Illinois Press, Chicago.

Lohr, V.I. and C.H. Pearson-Mims. 1996. Particulate matter accumulation on horizontal surfaces in interiors: Influence of foliage plants. Atmospheric Environment 30(14): 2565-2568.

Matsuo, E. 1999. Japanese perspectives in uses of flowers and plants for human well-being. Proceedings of International People-Plant Symposium; Towards a New Millennium of People-Plant Relationships. Sydney, Australia. pp.8-17.

Orwell, R., R. Wood, J. Tarran, F. Torpy and M.D. Burchett. 2003. Potential of potted-plants as a biofiltration system to improve indoor air quality, (submitted for publication).

Schempp, D. 2002. Green-architecture, plants in buildings, the cycle of nature, creating an inspiring, healthy indoor climate. Proceedings of International Plants for People Symposium . Amsterdam, NL.

Sim, W-K. 1999. A comparison of plant symbolisms between the Occidental and the Oriental. Proceedings of International People-Plant Symposium; Towards a New Millennium of People-Plant relationships. Sydney, Australia. pp.18-29.

Tarran, J., R. Orwell, M.D. Burchett, R. Wood and F. Torpy. 2002. Quantification of the capacity of Indoor Plants to Remove Volatile Organic Compounds under Flow-through Conditions, Final Report to Horticulture Australia.

Ulrich, R.S. 1999. Effects of gardens on health outcomes: theory and research. In: C. Cooper-Marcus and M. Barnes (eds.). Healing Gardens: Therapeutic benefits and Design Recommendations. John Wiley, NY. pp. 27-86.

Ulrich, R.S. 2002. Health benefits of gardens in hospitals. Proceedings of International Plants for People Symposium. Amsterdam, NL.

Ulrich, R.S. and R.P. Parsons. 1992. Influences of passive experiences with plants on individual well-being and health. In: D. Relf (ed). Human Benefits of Plants. Portland, Oregon. pp. 93-105.

Weschler, C. J. and H.C. Shields. 1997. Potential Reactions among indoor air pollutants. Atmospheric Environment 31 (21):3487-3495.

Whitehouse, S., J.W. Varni, M. Seid, C. Cooper-Marcus, M.J. Ensberg, J.J. Jacobs and R.S. Mehlenbeck. 2001. Evaluating a children's hospital environment: utilisation and consumer satisfaction. Journal of Environmental Psychology 21: 301-314.

Wolkoff, P. 1995. Volatile organic compounds - Sources, measurements, emissions and the impact on indoor air quality. Indoor Air. Suppl. No. 3.

Wolverton Environmental Services Inc. 1991. Removal of Formaldehyde from Sealed Experimental Chambers, by Azalea, Poinsettia and Dieffenbachia. Research Report No. WES/100/01-91/005.

Wolverton, B.C. and J.D. Wolverton. 1993. Plants and soil microorganisms - removal of formaldehyde, xylene and ammonia from the indoor environment. Journal of the Mississippi Academy of Science 38: 211-215.

Wood, R., M.D. Burchett, R.L. Orwell, J. Tarran and F. Torpy. 2002a. Plant/soil capacities to remove harmful substances from polluted indoor air. Proceedings of International Plants for People Symposium (Amsterdam, NL).

Wood, R., R. Orwell, J. Tarran, F. Torpy and M.D. Burchett. 2002b. Potted-plant / growth-media interactions and capacities for removal of volatiles from indoor air. Journal of Horticultural Science and Biotechnology 77: 120-129.