IJBES

International Journal of Built Environment and Sustainability
Published by Penerbit UTM Press, Universiti Teknologi Malaysia
IJBES 8(1)/2021, 57-67

Psychological And Physiological Benefits Of Plants In The Indoor Environment: A Mini And In-Depth Review

Lee Bak Yeo
School of Architecture, Faculty of Built Environment (FOBE), Tunku Abdul Rahman University College, Jalan Tun Razak 50400 Kuala Lumpur

ABSTRACT

People tend to spend approximately 87% of their time in the indoor environment. There is a possibility that they are exposed to volatile organic compound (VOC) and particle pollution, and to experience stress related disorder. This has potential threaten the well-being of indoor occupants if left untreated. Hence, plants were introduced to alleviate these negative impacts. This paper reviews past literature from 1990 to 2010s, to examine the relationship of plants with indoor environment and identifies how they influence people, psychologically and physiologically, and how they promote indoor environment quality. Most studies suggest that the presence of plants is associated with positive feelings and able to enhance productivity. In addition, they also may help to promote general health such as reducing blood pressure, perceived stress, sick building syndrome, and increase pain tolerance of the patient. Moreover, plants also help in improving the indoor environment quality (IEQ), for instance, they can reduce carbon dioxide (CO^2), indoor ozone (O^3) level, VOC, and particulate matter accumulation through bioremediation process. Despite all the benefits that the plants could offer, several studies pointed out that factors such as gender, perceived attractiveness of the space, physical characteristics of plants, and methods of interaction with plants may lead to non-identical results. Hence, the selection of the right species of plant in an indoor environment becomes mandatory in order to improve the indoor environment quality; to provide restorative effect; to invoke positive feelings and comfort of the people. In conclusion, this review may provide notable insights to landscape architects, gardeners and even interior designers to choose the right species of plant in an indoor environment, to maximize their psychological and physiological benefits, at the same time, improving indoor environment quality.

Article History

Received : 05 *May 2020*
Received in revised form :11 September *2020*
Accepted : 12 *October 2020*
Published Online : *31 December 2020*

Keywords:

indoor plants, indoor environment quality, psychological and physiological benefits, volatile organic compound

Corresponding Author Contact:

yeolb@tarc.edu.my

DOI: 10.11113/ ijbes. v8.n1.597

1. Introduction

The study of indoor environment in an urban setting has become a concern for scientific community because up to 87% of the people spending their time in the indoor environment, either in their residence (68.7%), office and factory (5.4%), bar and restaurant (1.8%), or inside a vehicle (5.5%) (Klepeis et al., 2001). One of the problems emerged is volatile organic compounds (VOC) outgassed from wood-based product and other household items that contributed to health risk (Aydogan and Montoya, 2011; Zhang et al., 2009). Moreover, particle pollution from outdoor environment that migrates to indoor environment can also negatively influence cardiopulmonary health (Stapleton and Ruiz-Rudolph, 2016). Other than that, lack of tranquillity in urbanized city also contributes to continual distraction, shorten attention span, and trigger stress related disorder, which may lead to psychological and physiological health disorder (Han, 2009).

Urbanization is defined in a different manner depended on its context of studies such as socio-economic and political studies, land use, population and place studies, but in general, it can be described as highly populated areas with a substantial of built-up areas and man-made features (Halfacree, 1993; MacKerron and Mourato, 2013; Yeo et al., 2019). Urbanization has been increasing from 30% in year 1950 to 55% in year 2018, and it is expected to keep increasing up to 68% in year of 2050, worldwide (UN, 2019). The continuous urban sprawl has contributed to the change of natural environment to agricultural land, and built-up areas (Yeo et al., 2019). Due to the increasing rate of urbanization, it is becoming difficult to access to natural landscapes (Turner et al., 2004). For instance, people that live in the urbanized city may not have the opportunity to visit such destination, or they might need to travel a longer distance. In fact, people are happier when engaging with green and natural environments as compared to urban environments (MacKerron and Mourato, 2013). Therefore, designing a greener indoor space is highly encouraged, to ensure that people stay in the indoor environment also have the opportunity to interact with nature, which in turn, may promote their comfortable level, productivity and mental functioning. Besides, the plants also help in reducing volatile organic compounds in the indoor environment (Teiri et al., 2018). Due to various benefits that the plant could offer, they were introduced to improve the indoor environment quality and to promote general well-being of the building occupants. The planting system can be vary and depended on the user needs, it can be a simple potted plant system, up to the advance technology likes green wall biofilter system (Irga et al., 2018). This paper firstly identifies how the plants in the indoor environment influence psychological and physiological health of the building occupants, and how they promote the indoor environment quality. Secondly, this paper presents a list of plant species that were being examined. So, future study can incorporate those species in their experimentation.

2. Method of Review

Mixed methods review was used in this research paper to review the relevant literature (Grant and Booth, 2009). Both quantitative and qualitative approaches were employed. In the quantitative approach, we elicited all the peer-review journals from year of 1990 to 2010s. Some of the keywords used to search the relevant articles included indoor plants/ vegetation/ potted plants, psychological benefits/ impacts, physiological benefits/ impacts, indoor environment quality/ air quality, and indoor environment/ setting/ space. The articles selected from peer-review journals are from the following disciplines, but not exclusively, *Indoor and Built Environment, Environment and Behaviour, Atmospheric Environment, HortScience, HortTechnology, and Indoor Air*. A list of 21 articles regarding how the plants contributed to the improvement of the indoor environment is tabulated. The tabulation is segregated into four categories, there are type of plant species, placement of plants (setting), type of improvement, and the authors (refer Table 1 and table 2). Firstly, the plants species used in this review are listed out in chronological order. Next, the placement of it is explained clearly in the table, e.g. the plants were put on a table or shelf. Lastly, how plants contributed to the well-being of building occupants and improve the environment quality, were explicitly presented in the table.

For qualitative approach, we separated the discussion into two sections. The first section is focused on the discourse of psychological (i.e. moods, feeling, performance, and stressors) and the physiological parameter (i.e. blood pressure, pain tolerance, anxiety, and fatigue), while the other section is focused on the indoor environmental quality (VOC, CO^2, ultra-fine particles). Both the positive and negative results are discussed and compared, in Sections 3 and 4.

3. Psychological and Physiological Benefits

One of the theories explains the benefits of engagament with nature is stress recovery theory by Ulrich (1983). For instance, Ulrich (1984) reported that patients viewed the nature outside of the windows had shorter postoperative hospital stays, and their attitudes also tend to be positive when interating with the hospital staffs, as compared to the patients that viewed the brick wall. Another theory that explains the benefits of nature is attention restoration theory (Kaplan and Kaplan, 1989). For instance, Kaplan (1995) found out that engaging with the natural environment has shown a few restorative benefits, which includes people have a propensity to, i) improve on their task performance, ii) help to mitigate stress related disorder and iii) enhance effective functioning.

There are substantial evidences support or partially support the attention restoration theory and stress recovery theory. For instance, Lohr et al. (1996) examined the impacts of the plants in a windowless computer lab, and they found out that people in lab with the presence of plants feeling more attentive and showed significant increases in their post-task attentiveness (12% faster in computer-based productivity). There are evidences provided by Larsen et al. (1998) and Thomsen et al. (2011) suggest that the plants may promote creative performance, reduce stress, improve mood and invoke positive feelings and comfort of the people. Nontheless, it is also worth to note that too many plants (17.88% of total space) in an office may not contribute to the improvement of productivity that required repetitive action with focused attention. Meanwhile, Bringslimark et al. (2007) suggest different views, their findings demonstrated that more plants in view in workplaces are associated with greater productivity and lesser sick leave, although the number of plants the researchers reported in their study are less than Larsen et al. (1998). Interestingly, Shibata and Suzuki (2004) postulate indoor plants may improve task performance of female occupants than male occupants. On the contrary, indoor plants may enhance the mood of male occupants than female occupants (ibid). In addition, there is evidence suggesting female occupants expressed more satisfaction than male occupants with the presence of plants in an interior rehabilitation centre (Raanaas et al., 2010). It means the impacts of plant on mood condition and task performance

Table 1 Plant species used in the indoor setting that promote psychological and physiological health

Type of Plant Species	Settings	Type of Improvement	Author(s)
Aglaonema sp.,Chamaedorea seifrizii, Dracaena marginata, Dracaena deremensis 'Janel Craig' ,Epipremnum aureum, Homalomena siesmeyeriana, Hoya sp., Philodendron scandens, Sansevieria trifasciata, Scindapsus pictus 'Argyraeus', Syngonium podophyllum	Floor, table, and hanging potted plants were placed in computer lab.	Feeling more attentive, rise in blood pressure was less, increases in post-task attentiveness, and reaction time on a computer-based productivity is increase by12%.	Lohr et al. (1996)
Aglaonema commutatum Schott, Dracaena deremensis 'Janel Craig' , Epipremnum aureum, Philodendron hederaceum, Dracaena fragrans, Philodendron cordatum.	Site 1: Potted plant placed on the window bench (office) Site2: On top of the film viewers (radiology department) Site 3: planter box near wall with bio process system	Complaints were decreased regarding: Site 1: Cough, fatigue, dry or hoarse throat, and dry or flushed facial skin. Site 2: Fatigue, feeling heavy-headed, headache, dry or hoarse throat, and hands with dry, itching, or red skin. Site 3: Headache and dry or hoarse throat.	Fjeld (2000)
Dracaena fragrans cv. Massangeana	Site 1: Room with potted plant Site 2: Magazine rack with book Site 3: No plant and no magazine rack	Female participants performed better than male with the presence of plants. Under no objects condition, both male and female felt less confident and less energized. Mood of male participants was better with the plant.	Shibata and Suzuki (2004)
Dracaena fragrans, Dracaena concinna, Epipremnum aureum, Ficus benjamina, Spathiphyllum wallisii, Beaucarnea recurvata, Schefflera arboricola	Plants were placed on shelves, the tops of filing cabinets, and on the floor in office environments	Plants has less statistically reliable associations with sick leave and productivity, and were not significantly associated with perceived stress due to the measure of stress was not specific to work-related circumstance.	Bringslimark, Hartig & Patil (2007)
Dendrobium phalaenopsis, Spathiphyllum 'Starlight', Epipremnum aureum, Syngonium podophyllum 'Albolineatum', Pteris cretica 'Albolineata', Vinca minor 'Illumination', Trachelospermum asiaticum 'Ogonnishiki'	Potted plants were placed in hospital room	Patients exposed to plants during recovery had significantly enhanced physiologic responses: improved mood and lower systolic blood pressure, lower ratings of pain, anxiety, and fatigue, and feeling more satisfied in hospital room. Patients increased interaction with plants: watering plants, removing dead leaves, touching them, and moving them for a better view or close to the window for better sunlight.	Park and Mattson (2009)
Dracaena reflexa, Rhapis excelsa, Schefflera arboricola, Dracaena surculosa, Epipremnum aureum, Liriope muscari, Aglaonema commutatum, Dracaena fragrans 'Janet Craig'	Potted plant placed on floor in a rehabilitation center	The plant intervention had a positive effect on satisfaction, which women were more satisfied with the interior design than men. No direct effect on self-report health outcome, probably due to the participants were mobile and received variety of treatment and activities at the center.	Raanaas, Patil & Hartig (2010)
Zanzibar Gem, Tradescantia spathacea	Potted plant and posters of plant in a hospital waiting room	Both real indoor plants and posters of plants were equally effective in reducing stress in patients because they improved the attractiveness of the room.	Beukeboom, Langeveld and Tanja-Dijkstra (2012)
Pelargonium odoratissimum, Alocasia Rhizome, Mentha haplocalyx, Lavandula (Lavender), Sansevieria trafasciata, Euphorbia pulcherrima (Poinsettia)	Potted plant in an office environment	Participants' satisfaction increase with slight scent plants (Lavender, S. trafasciata, Poinsettia, and A. rhizome) and small sized plants (Lavender, M. haplocalyx, P. odoratissimum), followed by medium and big sized plants.	Qin et al (2014)
Dracaena deremensis	Actual potted plant and picture of plant	Viewing actual plants may have psychological benefits not replicated by the image through increase Oxy-hemoglobin concentrations. Real plant and picture of plant, both induced feelings of comfort and relaxation.	Igarashi et al. (2015)
Epipremnum aureum	Vertical green system in a lab	Viewing foliage plants associated with positive images and feelings, but the density does not really affect people physiological parameters.	Choi et al. (2016)
Aglaonema commutatum, Epipremnum pinnatum	Potted plant in class room and hallway	Active engagement with plants provide greater stress restoration. Active and passive interaction with plants increase self-reported attention restoration. Distant of plant is not associated with positive impacts.	Han (2017)

for male and female occupants in the indoor environment are possibly non-identical. Future research can investigate this possibility more explicitly, to provide a more concrete evidence.

There is a raft of studies demonstrated that the presence of plants can help in reducing blood pressure (Lohr et al., 1996), perceive stress in a hospital environment, and pain tolerance (Dijkstra et al., 2008; Bringslimark et al., 2009). For instance, Park and Mattson (2009) reported that the patients exposed to plants during recovery had significantly enhanced physiologic responses (i.e. systolic blood pressure, pain tolerance, anxiety, and fatigue), evoked positive feelings and showed higher satisfaction about their hospital room. Another study by Beukeboom et al. (2012) posit both real plants and posters of plants are equally effective in reducing negative psychologic feelings of patients. It is due to both real plants and posters of plants improved the perceived attractiveness of the room. It happened because the stress reduction effect of plants are mediated by the perceived attractiveness of the space (Dijkstra et al., 2008). Besides, attractiveness factor, active interaction with plant also contributed to greater stress restoration, for instance, having physical activities in a garden/ yard, engagement in horticultural activities, gardening and farming (Han, 2017; Korpela et al., 2017). There is study suggested both real plants and the image of plants can induce feelings of comfort and relaxation. Nevertheless, real plants may provide better psychological benefits (Igarashi et al., 2015). The selection between real or image of plants in the indoor environment is therefore depended on the usages of the space. For instance, in a clinical environment, the image of plants maybe more suitable because some species of plant may trigger allergic reaction and infection. Meanwhile, in an office and a home environment with no occupants that are sensitive to infection or allergy, placement of real plants are highly encouraged. In fact, one study suggests that complaints regarding cough, fatigue, feeling of heavy-headed, headache, hoarse throat and dry or flushed facial skin were decreased by 23% to 37% with the presence of plant (Fjeld, 2000). There is also less reliable statistical finding of having more plants in view with lower stress (Bringslimark et al., 2007). The reasons might be due to the plants were perceived less attractive in the indoor environment (e.g. size, shape, species, and colour). For instance, the study of Qin et al. (2014) illustrated that the occupants showed highest degree of satisfaction when green, slight scent and small sized plants, are located in the office environment.

The results provided by Choi et al. (2016) showed no significant difference between the index of greenness (density) and psychophysiological stability, even a small amount of plants can bring positive impacts by stimulating the autonomic nervous system. Despite all the positive impacts that plants could offer, there is a study reported non-statistical significant results. For instance, Raanaas et al. (2010) reported that there is no significant association between the presences of plant with self-reported health in a rehabilitation centre. The insignificant results might be due to the participants were exposed to various treatments and activities taking place at the centre. Similarly, Shoemaker et al. (1992) found no direct association between plants with behaviour, attitudes and work satisfaction in the office environment, however, the employees felt calmer and relaxed with the presence of plants, and make the office a more desirable place to work in general. One of the reasons is that plants do not influence the employees' behavior, attitudes and work satisfaction might be because the employees already satisfied and enjoyed their jobs and the work environment. Hence, the presence of plants seemed to have relatively minor implications.

4. Indoor Environment Quality

Another role of plants is to improve the indoor environment quality (IEQ) and to promote general well-being of the people. Certain species of plants could effectively reduce the carbon dioxide, increase the comfort level in heated interior spaces, and reduce VOC and particulate matter accumulation (Lohr and Pearson-mims, 1996; Tarran et al., 2007). There is a plethora of study suggests the effectiveness of plants in helping to bring down the concentrations of VOC such as benzene, formaldehyde, and trichloroethylene (Wolverton et al., 1989.) Some of the VOC appear to have carcinogenic effects on humans, for example, formaldehyde from aging furniture and pressed wood products (Hun et al., 2010). Other than that, benzene and xylene are also confirmed carcinogens in which short term exposure to them may contribute to respiratory difficulties and feeling of discomfort. Meanwhile long-term exposure to them can result in neurotoxicity, respiratory disease and teratogenic effects (Wood et al., 2006). Hence, putting potted plants in the indoor environment will be a good option because they could act as a less expensive and sustainable indoor air purifier through bioremediation process. For instance, the evidences provided by Liu et al. (2007) demonstrated that there are ten species of plants could effective in reducing benzene, meanwhile three of the species (i.e. *C. portulacea, H. macrophylla and C. Golden Elf*) can remove benzene up to 80%. Similarly, Tarran et al. (2007) demonstrated that some species of plant can reduce total volatile organic compounds (TVOC) up to 75%. Moreover, Xu et al. (2011) discovered that *C. comosum*, *A. vera*, *E. aureum* removed more formaldehyde during day time because of higher photosynthesis and metabolism in plant under soil growing media, meanwhile Aydogan & Montoya (2011) found out that *H. helix* and *C. morifolium* showed quicker removal of formaldehyde under dark condition in hydroponic growing media. Similarly, Wood et al. (2002) provided evidence that *D. deremensis* 'Janet Craig' is effective in removing benzene, while H. Forsteriana is better in removing n-hexane. It is also worth to note that, plants in hydroponic growing media removed VOC slower than potting mix (ibid). This indicates different type of growing media, type of plant species and the light conditions may influence the uptake of VOC distinctively. Hence, introducing copious type of species of plants in the indoor environment are highly encouraged.

The production of CO^2 in the indoor environment is not as critical as VOC, but excessive CO^2 is likely to contribute to narcotic and sick building syndrome (Milton et al., 2000). Early study found out that some species of indoor plants can reduce

Table 2 Different type of plant species contribute to bring down VOC, CO_2, and particulate matter

Type of Plant Species	Settings	Type of Improvement	Author(s)
Aglaonema sp., Chamaedorea seifrizii, Dracaena marginata, Epipremnum aureum, Spathiphyllum sp.	Potted plant in a computer lab and office	Particulate matter on horizontal surfaces can be reduced up to 20%.	Lohr and Pearson-mims. (1996)
Howea forsteriana, Spathiphyllum wallisii, Draceana deremensis 'Janet Craig'	Potted plant and hydroponic, in a test chamber	D. deremensis is good in removing benzene, Howea is good in removing n-hexane.	Wood et al. (2002)
Dracaena deremensis 'Janet Craig', Spathiphyllum 'Sweet Chico',	Potted plant in an office environment	Potted-plants could deduce VOC up to 75%. Three floor-specimens of D. 'Janet Craig' are as effective as six. Potted-plants appeared equally effective under air-conditioned and non-air-conditioned circumstances	Wood et al. (2006)
Crassula portulacea, Hydrangea macrophylla , Cymbidium Golden Elf, Ficus microcarpa var. fuyuensis, Dendranthema morifolium, Citrus medica var. sarcodactylis, Dieffenbachia amona cv. Tropic Snow, Spathiphyllum Supreme, Nephrolepis exaltata cv. Bostoniensis, Dracaena deremensis cv. Variegata	Potted plant in test chamber	All 10 species of plant can remove more than 20% of benzene. C. portulacea, H. macrophylla and C. Golden Elf show notable high benzene removal up to 80%.	Liu et al. (2007)
Aglaonema modestum, Zamioculcas zamiifolia, Dracaena deremensis 'Janet Craig', Spathiphyllum 'Sweet Chico'	Potted plant in test chamber and office	Dracaena and Spathiphyllum (6 specimen) can reduce up to 75% TVOC. A. modestum and Z. zamiifolia can remove benzene (25ppm) effectively to zero in less than 48h. Dracaena reduced CO_2 by about 10% in air-conditioned building and 25% in the non-air conditioned building. CO cut down by 8% to 14% with or without air conditioning.	Tarran, Torpy and Burchett (2007)
Sansevieria trifasciata, Chlorophytum comosum, Epipremnum aureum	Potted plant in test chamber housed inside greenhouse	All plants in this study were effective in mitigating ozone, O_3.	Papinchak et al. (2009)
Chlorphytum comosum, Aloe vera, Epipremnum aureum	Potted plant in a test chamber	C. comosum attained the greatest formaldehyde removal capacity. More formaldehyde were removed during day time because higher photosynthesis and metabolism in plant.	Xu, Wang, Hou (2011)
Hedera helix, Chrysanthemum morifolium, Dieffenbachia compacta, Epipremnum aureum	Potted plant with growstone, expanded clay, and activated carbon under hydroponic growing media in a test chamber	All species can remove formaldehyde (around 90%). Activated carbon alone (AC) showed the highest formaldehyde removal at about 98%. All plants showed quicker removal of formaldehyde under dark condition excluding the aerial part of D. compacta and E. aureum.	Aydogan & Montoya (2011)
Aglaonema commutatum, Schott, Aspidistra elatior Blume, Castanospermum australe A. Cunn ex Hook., Chamaedorea elegans Willd. Dracaena deremensis 'compacta' Engl., Dypsis lutescens (H. Wendl.) Beentje & J., Dransf. Ficus benjamina L., Howea forsteriana Becc.	Potted plant in test chamber	CO_2 removal efficiency was high for two species, F. benjamina and D. lutescens C. elegans, A. commutatum and H. forsteriana recorded greater CO_2 reductions in the low light treatment (well-lit indoor light). H. forsteriana and D. lutescens were capable of net removal of CO2 at very low light levels. Dracaena 'Compacta' suitable for low light situation	Torpy, Irga, Burchett (2014)
Chamaedorea elegans, Peperomia jayde, Chlorophytum comosum 'variegatum', Dracaena deremensis 'Janet Crag', Ficus benjamina, Dracaena marginata, Schefflera arboricola 'Variegata', Juniperus chinensis 'San Jose', Sansevieria trifasciata, Sophora macrocarpa 'mayo', Quercus suber	Potted plant in a test chamber and outside of the chamber	F. benjamina, J. chinensis, significantly reduced UFP (diameter <100mm). Broad leaves, dense, and variegated surface area are effective in UFP reduction.	Stapleton and Ruiz-Rudlph (2016)

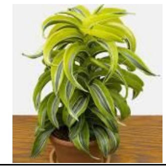
CO^2 up to 25%, for example, *F. benjamina, D. lutescens, D. 'Janet Craig'* are among the indoor plant species that are good in CO^2 reduction (Tarran et al., 2007; Torpy et al., 2014). The use of office printing machines, laser printers, ultraviolet lighting may also contribute to the increase of indoor ozone (O^3) level, which can negatively impact the human health. And to bring down O^3 level, placement of plants in the indoor environment will be a good choice (Papinchak et al., 2009). In addition to that, some of the indoor plants also help in reducing ultra-fine particle (UFP) accumulation, especially plants with broad leaves, variegated surface area and dense, are effective in UFP reduction (Stapleton and Ruiz-Rudlph, 2016). Despite all the benefits provided by potted plants as suggested in previous research, Moya et al. (2018) suggest that active vegetation system (green systems in combination with mechanical fans) performs more efficient than passive vegetation system (potted plant) in term of air cleaning rate. For instance, the use of vertical green system integrated into building ventilation system might be one of the possible solutions to promote indoor environmental quality even though the potency might not as good as the conventional HVAC filter (see Irga et al., 2018, p.406). Nonetheless, indoor plants still could help to reduce the dependence of HVAC ventilation, subsequently, reducing energy usage, greenhouse gas emission and carbon footprint (Torpy et al. 2014).

4. Findings and Future Study

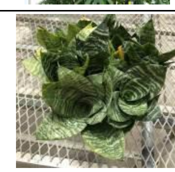
Out of 40 articles we had reviewed, only 21 articles were used in eliciting the plant species because some of the studies did not specify the type of species (e.g. Shoemaker et al., 1992; Larsen et al., 1998; Dijkstra et al., 2008; Korpela et al., 2018). All the plant species are listed in Table 3.0. It was found that *E. aureum* (10), *D. deremensis* '*Janet Craig*' (8) and *Spathiphyllum sp*. (7) are the most common plants being examined. All these plants have showed adequate positive results in the experiments. However, the researcher cannot verified that whether the psychological and physiological health benefits are actually provided by these plants. This is because in their research design, the experiments conducted was mixed with various other plant species. Nevertheless, there are significant evidences reported that *D. deremensis* '*Janet Craig*' and *Spathiphyllum sp*. are effective in removing VOC (e.g. Wood et al., 2002; Wood et al., 2006; Tarran et al., 2007). Other plant species such as *A. commutatum 'Schott'*(4), *C. comosum* (3), *D. marginata* (3), *S. trifasciata* (4), *S. arboricola* (3), and *P. hederaceum* (3) were also among few of the species that frequently being studied. Meanwhile, plant species such as *A. modestum, A. rhizome, A. vera* and some other species (see Table 3) are still not widely being investigated.

Table 3 Type of plant species used in the indoor environment. Pictures Source: EEOB (2020), NCSTATE (2020) and Plant Identification (n.d)

No.	Types of plant	Count	Pictures
1.	Aglaonema sp.	2	
2.	Aglaonema commutatum Schott	4	
3.	Aglaonema modestum	1	
4.	Alocasia Rhizome	1	
5.	Aloe vera	1	
6.	Aspidistra elatior Blume	1	
7.	Beaucarnea recurvate	1	
8.	Castanospermum australe A. Cunn ex Hook	1	
9.	Chamaedorea seifrizii	2	
10.	Chamaedorea elegans	2	
11.	Chlorophytum comosum	3	
12.	Chrysanthemum morifolium	2	

13.	Citrus medica 'sarcodactylis'	1	
14.	Crassula portulacea	1	
15.	Cymbidium Golden Elf	1	
16.	Dendrobium phalaenopsis	1	
17.	Dieffenbachia amoena 'Tropic Snow'	1	
18.	Dieffenbachia compacta	1	
19.	Dracaena concinna	1	
20.	Dracaena fragrans 'Massangeana'	2	
21.	Dracaena marginata	3	
22.	Dracaena deremensis 'Janet Craig'	8	
23.	Dracaena deremensis 'Compacta'	1	
24.	Dracaena deremensis 'Lemon Surprise'	1	
25.	Dracaena reflexa	1	
26.	Dracaena surculosa	1	
27.	Dracaena warnekii (variegata)	1	
28.	Dypsis lutescens	1	
29.	Epipremnum aureum	10	
30.	Epipremnum pinnatum	1	
31.	Euphorbia pulcherrima 'Ponsettia'	1	
32.	Ficus benjamina	2	
33.	Ficus microcarpa 'fuyuensis'	1	
34.	Hedera helix	1	

35.	Homalomena siesmeyeriana	1	
36.	Hoya sp.	1	
37.	Howea forsteriana	2	
38.	Hydrangea macrophylla	1	
39.	Juniperus chinensis ‘San Jose’	1	
40.	Lavandula (Lavender)	1	
41.	Liriope muscari	1	
42.	Mentha haplocalyx	1	
43.	Nephrolepis exaltata 'Bostoniensis'	1	

44.	Pelargonium odoratissimum	1	
45.	Peperomia jayde	1	
46.	Philodendron scandens/cordatum/ hederaceum	3	
47.	Pteris cretica ‘Albolineata’	1	
48.	Quercus suber	1	
49.	Rhapis excelsa	1	
50.	Sansevieria trifasciata	4	
51.	Schefflera arboricola	3	
52.	Scindapsus pictus 'Argyraeus'	1	
53.	Sophora macrocarpa ‘mayo’	1	
54.	Spathiphyllum sp./ 'Supreme'/ ‘Sweet Chico’/ wallisii 'Startlight'	7	

55.	Syngonium podophyllum 'Albolineatum'	2	
56.	Vinca minor 'Illumination'	1	
57.	Trachelospermum asiaticum 'Ogon nishiki'	1	
58.	Tradescantia spathacea	1	
59.	Zamioculcas zamiifolia	2	

From the past studies, it is clear that indoor environmental quality plays important role in general well-being of building occupants and interacting with plants can positively change psychological and physiological responses. Previous investigations have emphasized the advantages of including plants in the indoor environment. Nevertheless, one dimension still can be further investigated is the physical characteristic of plants, and their composition in order to improve the overall attractiveness of the room. Qin et al. (2014) also suggest the same, there is a lack of study on plants' inherent characteristics such as colour, odour and size on human comfort. Other than that, the distance between the positions of the plant with the occupants also show inconsistent results (Han, 2017). Hence, future study can seek to explore on the different type of composition (size, colour and smell) of plants and their arrangements (location and proximity).

5. Conclusion

The inclusion of plants in an indoor environment may positively impact our psychological response and physiological health. However, not all of them have shown adequate correlational positive results. And often the results are highly regulated by several factors such as different in gender may express dissimilar level of satisfaction, and different physical characteristics of plants may change the perceived attractiveness of the space and thus affecting the efficacy of stress reduction. Nevertheless, the functions of plants to improve the indoor environment quality through bioremediation are undeniable. Thus, people are becoming more interested to place the plants in their indoor environment, not just mainly for the restorative effect that plants could offer, but also for their function as a low-cost air purifier. This review has shown substantial evidences on how plants can contribute to the betterment of indoor environment and how they improve the psychological and physiological health of the occupants. In practice, this review opens a new insight for the landscape architect, interior architect and designer to select the appropriate type of plant species in an indoor environment, not just purely for the aesthetic aspects, but also the functional aspects.

References

Aydogan, A., & Montoya, L. D. (2011). Formaldehyde removal by common indoor plant species and various growing media. *Atmospheric Environment*, 45(16): 2675–2682.

Beukeboom, C. J., Langeveld, D., & Tanja-Dijkstra, K. (2012). Stress-Reducing Effects of Real and Artificial Nature in a Hospital Waiting Room. *The Journal of Alternative and Complementary Medicine*, 18(4): 329–333.

Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, 29(4): 422–433.

Bringslimark, T., Hartig, T., & Patil, G. G. (2007). Psychological benefits of indoor plants in workplaces: Putting experimental results into context. *HortScience*, 42(3): 581–587.

Choi, J., Park, S., Jung, S., Lee, J., Son, K., An, Y., & Lee, S. (2016). Complementary Therapies in Medicine Physiological and psychological responses of humans to the index of greenness of an interior space. *Complementary Therapies in Medicine*, 28: 37–43.

Dijkstra, K., Pieterse, M. E., & Pruyn, A. (2008). Stress-reducing effects of indoor plants in the built healthcare environment: The mediating role of perceived attractiveness. *Preventive Medicine*, 47(3): 279–283.

Fjeld, T. (2000). The effect of interior planting on health and discomfort among workers and school children. HortTechnology, 10(1): 46–52.

Grant M. & Booth A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information and Libraries Journal*, 26: 91–108.

Halfacree K.H. (1993). Locality and social representation: space, discourse and alternative definitions of the rural. *Journal of Rural Studies*, 9(1): 23-37.

Han, K. T. (2009). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior*, 41(5): 658–692.

Han, K. T. (2017). Influence of passive versus active interaction with indoor plants on the restoration, behaviour and knowledge of students at a junior high school in Taiwan. *Indoor and Built Environment*, 0(0), 1–13.

Hun, D.E., Corsi R. L., Morandi, M. T., & Siegel, J. A. (2010) Formaldehyde in residences: long-term indoor concentrations and influencing factors. *Indoor Air*, 20: 196–203.

EEOB (2020). Plant Index. Department of Ecology, Evolution, and Organismal Biology, Iowa State University. Retrieved from https://www.eeob.iastate.edu/greenhouse/plant. [Accessed on 8 September 2020].

Irga, P. J., Pettit, T. J., & Torpy, F. R. (2018). The phytoremediation of indoor air pollution: a review on the technology development from the potted plant through to functional green wall biofilters. *Reviews in Environmental Science and Biotechnology*, 17(2): 395–415.

Igarashi M, Song C, Ikei H, Miyazaki Y. (2015). Effect of stimulation by foliage plant display images on prefrontal cortex activity: a comparison with stimulation using actual foliage plants. *Journal of Neuroimaging,* 25(1):127–130.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15: 169-182.

Kaplan R and Kaplan S. (1989). The experience of nature: a psychological perspective. New York, NY: Cambridge University Press.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Engelmann, W. H. (2001). The National Human Activity Pattern Survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, 11(3): 231–252.

Korpela, K., Bloom, J. De, Sianoja, M., Pasanen, T., & Kinnunen, U. (2017). Landscape and Urban Planning Nature at home and at work: Naturally good? Links between window views, indoor plants, outdoor activities and employee well-being over one year. *Landscape and Urban Planning*, 160: 38–47.

Larsen, L., Jeffrey, A., Deal, B., Kweon, B., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. *Environment and Behavior*, 30(3): 261–281.

Liu, Y. J., Mu, Y. J., Zhu, Y. G., Ding, H., & Crystal Arens, N. (2007). Which ornamental plant species effectively remove benzene from indoor air? *Atmospheric Environment*, 41(3): 650–654.

Lohr, V. I., Pearson-mims, C. H., & Goodwin, G. K. (1996). Interior plants may improve worker productivity and reduce stress in a windowless environment. *Journal of Environmental Horticulture Article*, 14(2): 97–100.

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

Larsen, L., Jeffrey, A., Deal, B., Kweon, B., & Tyler, E. (1998). Plants in the workplace: The effects of plant density on productivity, attitudes, and perceptions. *Environment and Behavior*, 30(3): 261–281.

Mackerron, G., & Mourato, S. (2013). Happiness is greater in natural environments. Global Environmental Change, 23(5): 992–1000.

Moya, T. A., van den Dobbelsteen, A., Ottelé, M., & Bluyssen, P. M. (2018). A review of green systems within the indoor environment. *Indoor and Built Environment*, 0(0): 1–12.

Milton, D.K., Glencross, P.M., Walters, M.D. (2000). Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints. *Indoor Air*, 10: 212–221.

NCSTATE (2020). North Carolina Plant Toolbox. Retrieved from https://plants.ces.ncsu.edu/find_a_plant/ [Accessed on 8 September 2020]

Papinchak, H. L., Holcomb, E. J., Best, T. O., & Decoteau, D. R. (2009). Effectiveness of houseplants in reducing the indoor air pollutant ozone. *HortTechnology*, 19(2): 286–290.

Park, S.-H., & Mattson, R. H. (2009). Ornamental indoor plants in hospital rooms enhanced health outcomes of patients recovering from surgery. *Journal of Alternative and Complementary Medicine*, 15(9): 975–980.

Qin, J., Sun, C., Zhou, X., Leng, H., & Lian, Z. (2014). The effect of indoor plants on human comfort. *Indoor and Built Environment*, 23(5): 709–723.

Raanaas, R. K., Patil, G. G., & Hartig, T. (2010). Effects of an indoor foliage plant intervention on patient well-being during a residential rehabilitation program. *HortScience*, 45(3): 387–392.

Shibata, S. & Suzuki, N. (2004). Effects of an indoor plant on creative task performance and mood. *Scandinavian Journal of Psychology*, 45: 373–381.

Shoemaker, C. A., Randall, K., Relf, P. D., & Geller, E. S. (1992). Relationships between plants, behavior, and attitudes in an office environment. *HortTechnology*, 2(2): 205–206.

Stapleton, E., & Ruiz-Rudolph, P. (2016). The potential for indoor ultrafine particle reduction using vegetation under laboratory conditions. *Indoor and Built Environment*, 27(1): 70–83.

Tarran, J., Torpy, F., Burchett, M.D. (2007). Use of living pot-plants to cleanse indoor air – research review. In: Proceedings of the Sixth International Conference on Indoor Air Quality, Ventilation & Energy Conservation in Buildings – Sustainable Built Environment, Sendai, Japan, 249–256.

Turner, W. R., Nakamura, T., & Dinetti, M. (2004). Global Urbanization and the Separation of Humans from Nature. *Bioscience*, 54(6): 585–590.

Teiri, H., Pourzamani, H., & Hajizadeh, Y. (2018). Chemosphere Phytoremediation of VOCs from indoor air by ornamental potted plants: A pilot study using a palm species under the controlled environment. *Chemosphere*, 197: 375–381.

Thomsen, J. D., Sønderstrup-Andersen, H. K. H., & Muller, R. (2011). People-plant relationships in an office workplace: perceived benefits for the workplace and employees. *HortScience*, 46(5): 744–752.

Torpy, F. R., Irga, P. J., & Burchett, M. D. (2014). Profiling indoor plants for the amelioration of high CO2 concentrations. *Urban Forestry and Urban Greening*, 13(2): 227–233.

Ulrich R.S. (1983) Aesthetic and Affective Response to Natural Environment. In: Altman I., Wohlwill J.F. (eds) Behavior and the Natural Environment. Human Behavior and Environment (Advances in Theory and Research), vol. 6. Springer, Boston, MA.

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647): 420–421.

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420). New York: United Nations.

Wood, R. A., Orwell, R. L., Tarran, J., Torpy, F., & Burchett, M. (2002). Potted-plant/growth media interactions and capacities for removal of volatiles from indoor air. *Journal of Horticultural Science and Biotechnology*, 77(1): 120–129.

Wood, R. L., Burcheftt, M. D., Alquezar, R., Orwell, R. L., Tarran, J., & Torry, F. (2006). The potted-plant microcosm substantially reduces indoor air VOC pollution: I. office field- study. *Water, Air, and Soil Pollution*, 175(1–4): 163–180.

Wolverton B. C., Johnson A. and Bounds K. (1989). Interior Landscape Plants for Indoor Air Pollution Abatement. National Aeronautics and Space Administration, Stennis Space Center, Mississippi.

Xu, Z., Wang, L., & Hou, H. (2011). Formaldehyde removal by potted plant – soil systems. *Journal of Hazardous Materials*, 192(1): 314–318.

Yeo, L. B., Said, I., Saito, K., & Fauzi, A. M. (2017). Mapping land use/ cover changes and urbanization at sub-districts of Muar, Malaysia. *Chemical Engineering Transactions*, 56: 289-294.

Zhang, L., Steinmaus, C., Eastmond, D.A., Xin, X.K., Smith, M.T. (2009). Formaldehyde exposure and leukemia: a new meta-analysis and potential mechanisms. *Mutation Research*, 681: 150-168.