Create Awareness on Users about the Use of Greenery to Remove Air Pollution in Commercial Interiors

NAZLI NAZENDE YILDIRIM
Department of Interior Architecture and Environmental Design
Atilim University
Kizilcasar Mahallesi, 06836, İncek Gölbaşı, Ankara
TURKEY
nazli.yildirim@atilim.edu.tr http://ict.atilim.edu.tr/personel/personInfo/id/374?lang=tr

Abstract: - Indoor air quality is quite affect human health. Users spend time in many different interior places such as homes, offices, schools, public transportation vehicles, theaters, restaurants, etc. However, recent researches show that the indoor/outdoor pollutant ratios at commercial interiors were higher than those places. Over the last three decades solid empirical evidence about indoor plants that removes negative effects of indoor air pollutants has found. This paper introduces correlation between indoor air quality and greenery in commercial interiors. The central aim of this research is to create user awareness the issue of improving the indoor air quality of commercial interiors by using suitable indoor plants. In this context, in the research was conducted a comparative study on user preferences for the living wall designed two different forms in the commercial interior. The result of the research showed that participants prefer Store 2 containing the living wall designed with multiple plants than Store 1 containing the living wall designed with a single species of plant.

Key-Words: - Indoor air pollution, indoor air pollutants, greenery, commercial interiors

1 Introduction

The World Health Organization (WHO) reports that people spend 90% of their time indoors and they are not aware of what are exposed to in these areas. In the 1950s, indoor air quality (IAQ) was for the first time the world's agenda when correlations between indoor air pollution (IAP), allergies and other chronic illnesses were recognized [1, 2]. IAP was aggravated by the energy crisis of 1970s; buildings were designed to maximize energy efficiency to help reduce energy costs. For this reason, airtight buildings that included super insulation and reduced fresh air exchange changes appeared. In these buildings synthetic materials that final petroleum products such as particle boards, synthetic fibers and plastics were being used instead of natural materials such as wood, marble and natural fibers. The users of the building began to complain of various health problems such as itchy eyes, skin rashes, drowsiness, respiratory and sinus congestion, headaches, and other allergy-related symptoms. [3,4,5,6,7,8]. All of these factors have caused an illness called Sick Building Syndrome (SBS) [9, 10]. In the 1970s, The National Aeronautics Space Administration (NASA) identified indoor air pollution problems by determining 107 Volatile Organic Compounds (VOCs) emitted synthetic materials in spacecraft. Thus, the NASA conducted a research on the use of living plants to purify and revitalize indoor air [7]. Dr. Bill Wolverton, the NASA's Professors, conducted many experiments on the ability of interior plants to remove IAP [11, 12, 13, 14, 15]. On the other hand, concurrently with these researches, some researches experimentally studied the influence of greenery on human attitudes and functioning. Studies showed that greenery in people living areas can enhance and offer benefits such as psychological recreation and environmental improvement [16, 17]. Furthermore, some experiments and psychology suggests that the interaction with green has relaxing effects such as lowered diastolic blood pressure and heart rate [18, 19, 20, 21, 22]. At this point, previous studies demonstrated that the plants used interior spaces provide benefits in many ways to user health and IAQ. However users do not have any awareness of this issue [8, 23]. Today because of in cities space is limited at ground level, vertically it is not, the concept of vertical vegetation be exist. This vertical vegetation, which has been referred as "vertical gardens, "living walls" or "green walls" begin to have high aesthetic impact and value in homes, offices and commercial interiors [24]. The purpose of this paper establishing correlation indoor plants removed IAP and living walls to suggest greenery having both functional and aesthetic value.

In this respect, indoor air quality of commercial interiors and the use of greenery in commercial

interiors as well as possible sources discussed in this paper are summarized the recommendation put forward to increase the users' awareness in the conclusion part.

2 Indoor Air Pollution (IAP) and Indoor Air Pollutants (IAPS)

IAP occurs depends on many different factors caused by indoor/outdoor. IAP consists of pollutant sources such as outdoor air, soil, water, building envelope, building equipment, finishes and furnishings, machines and appliances, occupants, occupant activities, maintenance and cleaning [25]. These sources emit some pollutants such as bio-aerosols (bacteria, fungi, fungal spores, viruses, pollen and all organic dust containing the particles of these bio-aerosols), tiny particular materials (particles created by combustion of diesel fuels, cigarette smoke, fired-up stove or cooking), volatile organic substances (formaldehyde, xylene, toluene, ethylbenzene, benzene, trichloroethylene, etc.), pesticides (pesticides and other chemical materials killing fungi and bacteria), pollutant gases (carbon dioxide, carbon monoxide, ozone, sulfur dioxide, nitrogen oxides, asbestos and radon) and radiation [26]. Researhes demonstrated that especially the large part of IAP is occured by means of volatile organic compounds (VOCs) in commercial interiors [27, 28, 29, 30]. For this reason, in this part of the study is focus on VOCs.

2.1 Volatile Organic Compounds (VOCs)

VOCs in indoor air, indicated that building related materials including furniture and equipment and consumer and household related products are major VOC sources [31, 32, 33, 34, 35, 36]. VOCs include adhesives, caulks, sealants, paints, solvents, varnishes, detergents, wood stain, floor wax, carpets, textiles, wallboard, treated wood, urethane coatings, pressed-wood products, vinyl flooring, fabrics and can also be emitted by the use of other products, such as printers, photocopiers [37, 38]. As it seen Table 1, Dr. Bill Wolverton defined interior emission sources [7-55]. VOCs may cause reduced worker productivity and acute health effects such as eye, nose and throat irritation, headaches, fatigue, nausea, loss of coordination, damage to liver, kidney and central nervous system, sinus congestion and asthmatic symptoms etc. to short-term exposure. Nevertheless, long-term exposure may cause cancers [38, 39, 40, 41]. In the context of this study is investigated VOCS as formaldehyde, benzene, trichloroethylene, toluene, xylene and ethylbenzene the most common in commercial interiors.

Table 1. Interior Emission Sources

Chemical Emission Sources	Formaldehyde	Xylene/ Toluene	Benzene	TCE
Adhesive Materials	x	x	x	-
Biologic Substances	-	x	-	-
Carpets and Fabrics	x	-	-	-
Bonding Elements	x	x	x	-
Interior Coating	x	x	x	-
Cosmetic Products	-	-	-	-
Printers and Printed Materials	-	x	x	x
Particle Boar	x	x	x	-
Plywood	x	-	-	-
Painting and Varnish	x	x	x	-
Tobacco Smoke	x	-	x	-

TCE: Trichloroethylene.

2.1.1 Formaldehyde

Formaldehyde is a ubiquitous chemical known irritant and carcinogen found in all indoor environments. Formaldehyde is found foam insulation and particle board or pressed-wood products. Besides, many consumer paper products such as grocery bags, waxed papers, facial tissues, and paper towels, are processed with urea formaldehyde resins. These resins present in floor covering, carpet backing, and permanent-press fabrics. Many common household cleaning agents include formaldehyde. Cigarette smoke and heating and cooking fuels such as natural gas and kerosene include formaldehyde. The National Toxicology Program defines formaldehyde as reasonably anticipated to be a human carcinogen [7, 42, 43, 56].

2.1.2 Benzene

Benzene is a very commonly used solvent and is also found such as gasoline, inks, oils, paints plastics, and rubber. Furthermore, detergents, explosives, pharmaceuticals, and dyes include benzene. The World Health Organization is

classified benzene as known and possible human carcinogens [7, 43, 44].

2.1.3 Trichloroethylene

Trichloroethylene is a commercial product generally used in the metal degreasing and dry-cleaning industries and is also used printing inks, paints, lacquers, varnishes, and adhesives. Trichloroethylene is considered as a potent liver carcinogen chemical by the National Cancer Institute [7].

2.1.4 Toluene

Toluene is used as a high-octane blending stock in gasoline; as a solvent for paints and coatings, gums, resins, oils, rubber and adhesives; and as an intermediate in the preparation of chemical products, dyes, pharmaceuticals and detergents. Therefore, studies showed that toluene emitted from some building materials as furniture, floor, wall coverings, wallpapers, gypsum blocks and panels used in wall construction. Also, toluene presents in cosmetics products such as nail polishes [8, 43, 44, 45, 46].

2.1.5 Xylene and Ethylbenzene

Xylenes and ethylbenzene are chemicals in a group of VOCs that pollute indoor air. Ethylbenzene is used in paints, lacquers, artificial wood and insecticides and xylene present in artificial wood, wood varnish, paints protective coatings, and is used as a solvent for alkyd resins, lacquers, enamels and rubber cements [8, 43, 44, 45, 47].

3 Greenery

Plants are very important for the earth because of they produce the oxygen that makes life possible, add precious moisture and filter toxins. Plants can be described as the lungs of the earth [41]. In heated interior spaces, plants increase the comfort level for users by the way of indoor relative humidity by releasing moisture into the air [48].

Researches demonstrated that low-light-requiring indoor plants are used as the potential for improving indoor air quality by removing trace organic pollutants from the air in energy-efficient buildings. For removing volatile organic chemicals, the plant root-soil zone is the most effective area so maximizing air exposure to the plant root-soil area should be considered when placing plants in buildings for effective air filtration. In this way, indoor plants are important factor for solving indoor air pollution problems [7].

Previous studies stated that people prefer natural (green, etc) environments than environments dominated by arte facts. The quality of green spaces has a relationship to people's mood and it can put a positive mood [17, 22].

3.1 Indoor Plants

Studies showed that multiple species of indoor plants removed IAPS in a particular space [11, 12, 13, 14, 15, 57, 58]. Dr. Bill Wolverton stated that these IAPS are converted into food and energy sources by plants through metabolic degradation [59].

In these studies aloe vera, golden pothos (Scindapsus aureus), nephthytis (Syngonium podophyllum), spider plant (Chlorophytum comosum), pot mum (Chrysanthemum morifolium), english ivy (Hedera helix), dump cane (Dieffenbachia compacta) removed formaldehyde [12, 15, 49, 50]. English ivy (Hedera helix), peace lily (Spathiphyllum ‘mauna loa’), madagascar dragon tree (Dracaena marginata), janet craig (Dracena deremensis) dispelled benzene. Peace lily (Spathiphyllum ‘mauna loa’), pot mum (Chrysanthemum morifolium) removed trichloroethylene. Tolune was eliminated snake plant (Sansevieria trifasciata) and mother-in-law’s tongue (Sansevieria hyacinthoides). Xylene was dispelled zanzibar gem (Zamioculcas zamiifolia). Spider plan (Chlorophytum comosum), snake plant (Sansevieria trifasciata) and mother-in-law’s tongue (Sansevieria hyacinthoides) removed ethylbenzene [45, 59, 60].

3.2 Living Walls

In recent years it was very common encounters with the concept of living walls in the field of architecture, interior architecture and landscape architecture. However, date of this concept goes back to the 1930s. Stanley Hart White, Professor of Landscape Architecture at the University of Illinois Urbana, is known as an inventor and technological innovator, conceptualizing the living wall and pioneering green modernism. White’s first sketch of the green wall seen in Figure 1. He patented the first known green wall in 1938 [61].

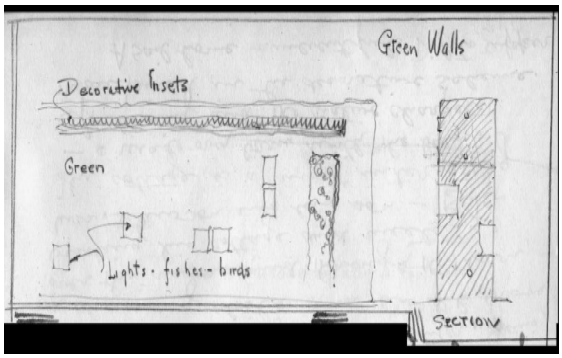

Figure 1. First Sketch of a 'Green Wall' by Stanley Hart White (1932) [61].

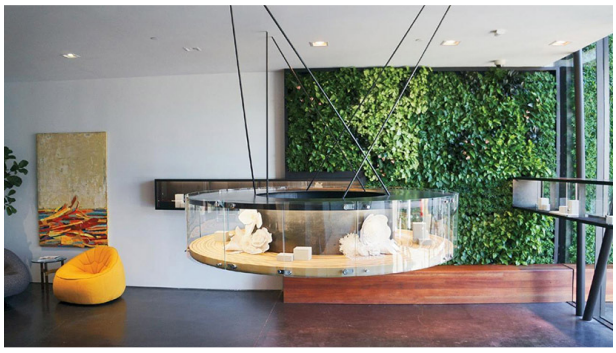

Figure 2. Store 1: Living Wall Designed with a Single-Type of Plant [63].

Figure 3. Store 2: Living Wall Designed with multiple plants. [63].

At the present time, the living walls in façades or interiors the most innovative and powerful tools for the bioclimatic and sustainable design especially very limited places [51]. Furthermore, created environmental consciousness consumers in commercial interiors can affect consumer's purchasing decisions. Living walls in commercial interiors is one the most effective ways in the process affecting consumers. At the same time, living walls used inside the store behave like a sound dampener while reducing air pollution, heat and adding color to the space [52]. Living walls quiet adds an aesthetic value to the building. Living walls is able to bring nature closer to users. Although the appearance of these living walls based on former, there is lack of awareness of the benefits and performance of living walls [53, 54]. Notedly, for the prevention of IAP, consciously plant selection is not done in the living walls.

4 Method

Case study was envisaged to conduct questionnaire with the participants face to face as the method to collect data. First, photos of same stores have different living walls were projected on the screen with projection device in conference room. Store 1 contained the living wall designed with a single species of plant. This plant was golden pathos. Store 2 included the living wall designed with multiple plants. These plants were aloe vera, golden pothos, spider plant, peace lily, dump cane (see Figure 2 and Figure 3). All of the participants were taken to conference room. Photos of the Store 1 and the Store 2 were projected on the screen. The question that which store do you prefer to shopping? was asked to participants.

4.1 Participants

The main participant group of the study is constituted by 38 person who potential customers with members of the Atilim University as academic staffs, administrative staffs and students. 20 of the participants are woman and 18 of are man.

4.2 Procedure

The research was conducted by using closed-ended structured interviewing method [64]. The closed-ended questions have a question format that limits respondents with a list of answer choices from which they must choose to answer the question in the form of multiple choices [65]. The correlation between the dependent and independent variables related for determination of evaluations made to reveal the living wall preferences of users were analyzed by Chi-Square test. However, although the minimum expected count is 6,16, in the data analysis of questionnaire were used method of Continuity Correction Statistic (see Table 2) [66]. SPSS (Statistical Package for the Social Sciences) Statistical Package Program and 'Microsoft Office Excel' programs were used for data analysis.

Table 2. Data Analyses

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	,333[a]	1	,564		
Continuity Correction[b]	**,055**	**1**	**,815**		
Likelihood Ratio	,333	1	,564		
Fisher's Exact Test				,734	,407
Linear-by-Linear Association	,324	1	,569		
N of Valid Cases	38				

a. 0 cells (0,0%) have expected countless than 5. The minimum expected count is 6,16.
b. Computed only for a 2x2 table

5 Results and Discussion

While 52.6% of the participants are women and 47.4% of are men. Results demonstrate that 65, 8% of the participants prefer to Store 2. 32, 8% of the participants prefer to Store1 (see Table 3)

Table 3. Demographic Information

		n	%
Gender	Man	18	47,4
	Woman	20	52,6
Which store do you prefer to do shopping?	Store 1	13	34,2
	Store 2	25	65,8

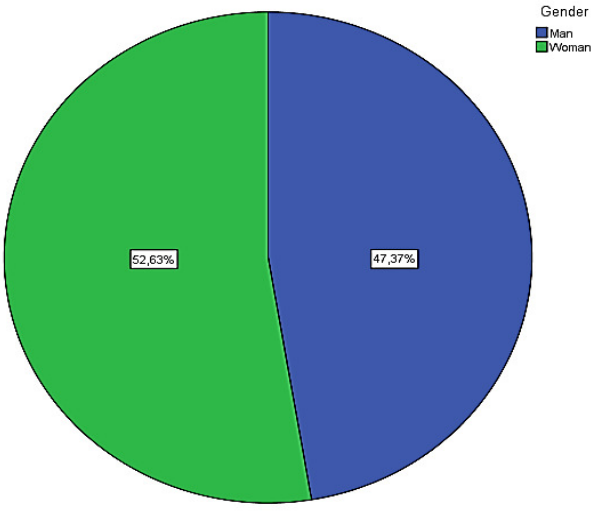

Figure 4. Demographic Information

Results show that Store 2 is preferred by the majority of woman and man participants (70,0% woman- 61,1% man). Whereas Store 2 is mostly preferred by woman participants (56,0%), store 1 is usually preferred by man participants (53,8%). Results of Chi-Square (Continuity Correction Statistic) tests did not reveal a statistically significant difference (p>0,05) between gender and store preferences.

Table 4. Range of the Gender according to User Store Preferences and Correlation Analysis

			Which store do you prefer to do shopping?		Total
			Store 1	Store 2	
Gender	**Man**	n	7	11	18
		%Gender	38,9%	61,1%	100,0%
		%Which store do you prefer to do shopping?	53,8%	44,0%	47,4%
	Woman	n	6	14	20
		%Gender	30,0%	70,0%	100,0%
		%Which store do you prefer to do shopping?	46,2%	56,0%	52,6%
Total		n	13	25	38
		%Gender	34,2%	65,8%	100,0%
		%Which store do you prefer to do shopping?	100,0%	100,0%	100,0%

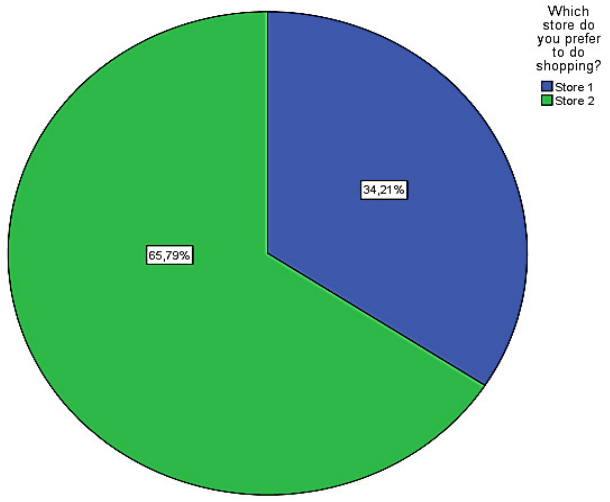

Figure 5. Range of the Gender according to User Store Preferences

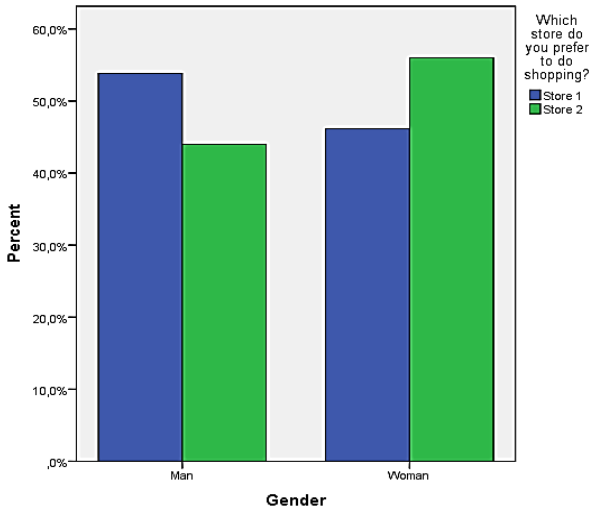

Figure 6. Range of the Gender according to User Store Preferences and Correlation Analysis

6 Conclusion

The literature review about IAP and IAPS demonstrated that indoor air is quite dirty for many reasons in today. Hence, people using these spaces are exposed to IAPS generated by many different sources. Especially due to commercial interiors working as the social center of a community, people spend time with friends and/or family in these places as long as they get goods and services. Therefore, people spend a long time depending on several reasons in commercial interiors. People have the chance choosing their location, furniture of homes and offices but they do not have such a chance in commercial interiors. It is important that the IAP of commercial interiors is more than other places such as home, office, etc. because of their locations and products.

It is presented that many indoor plants such as aloe vera, golden pothos, nephthytis, spider plant, pot mum, english ivy, dump cane, peace lily madagascar dragon tree, janet craig, snake plant, mother-in-law's tongue, zanzibar gem remove IAPS in interior places. However, users and interior architects do not have the awareness of benefits these plants. Nowadays, although living walls in interior places are used very commonly, they are design only with aesthetics concern. Living walls can be gained to a very significant function. If these living walls are design with the beneficial indoor plants, users and interior architects can become conscious about this issue and the living walls may have both aesthetics and functional characterize. In this way, these plants and the concept of 'greenery' from being a decorative element, they can be a real interior design element.

This study is an introduction which living walls designed with beneficial indoor plants are used to remove IAPS in commercial interiors to attract attention of users. In this context, the living wall preferences of the users were investigated in order to raise greenery removed air pollution awareness with this study. The store containing the living wall designed with multiple plants was preferred by users. On account of this, living walls in commercial interiors may be designed with more than one beneficial plant species as collage.

Further studies can be brought alternative living wall form suggestions with designed beneficial indoor plants for a particular interior places. Moreover, correlation between living walls designed different each other and user behaviors can be studied by empirical studies in commercial interiors.

References:

[1] Randolph, G.T., Ralph, W.M., *An Alternative Approach to Allergies,* Harper and Row Publishers, New York, NY, 1980.

[2] Weschler, C.J., Changes in Indoor Pollutants Since the 1950s, *Atmospheric Environment,* No.43, 2009, pp.153-169.

[3] Harriman, L., Brundrett, G., Kittler, R., Humidity Control Design Guide for Commercial and Institutional Buildings, *American Society of Heating, Refrigerating, and Air-Conditioning Engineers*, 2001, Atlanta, GA.

[4] Kibert, J.C., *Sustainable Construction: Green Building Design and Delivery*. John Wiley & Sons, Inc, Hoboken, NJ, 2008.
[5] ASHRAE, ANSI/ASHRAE/USGBC/IES Standard 189.1e2009, Standard for the Design of High-Performance Green Buildings. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, 2009.
[6] Persily, A.K., Emmerich, S.J., Indoor Air Quality in Sustainable, Energy Efficient Buildings, *In: Proceedings of IAQVEC 2010*, pp. 1-12, Syracuse NY, August 15-18, 2010.
[7] Wolverton BC, Johnson A, Bounds K., Interior Landscape Plants for Indoor Air Pollution Abatement, NASA/ALCA Final Report, *Plants for Clean Air Council.* Davidsonville, Maryland 1989. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19930073077.pdf
[8] Yildirim, K., Ünlü, F., Determination of Users' Knowledge on the Impact of Organic Chemicals in Interior Equipment Elements on Health: Ankara/Turkey Sample, *Open Environmental Sciences,* 2013, Vol.7, pp. 32-40.
[9] Kostiainen, R., Volatile Organic Compounds in the Indoor Air of Normal and Sick Houses, *Atmospheric Environment,* 1995, Vol.29, pp.693-702.
[10] Brasche, S., Bullinger, M., Gebhardt, H., Herzog, V., Hornung, P., Kruppa, B., Meyer, E., Morfeld, M., Schwab, R.V., Mackensen, S., Winkens, A., Bischof, W., lsquoFactors Determining Different Symptom Patterns of Sick Building Syndrome - Results From a Multivariate Analysis, In: Paper read at Proceedings of the 8th International Conference on Indoor Air Quality and Climate, at Edinburgh, Scotland, 1999.
[11] Wolverton, B.C., Plants and Their Microbial Assistants: Nature's Answer to Earth's Environmental Pollution Problems, *Biological Life Support Technologies: Commercial Opportunities Workshop*, 1989.
[12] Wolverton, B.C., Wolverton, J., Removal of Formaldehyde from Sealed Chambers by Azalca, Poinsettia and Diffenbachia, *Plants for Clean Air Council,* 1991a, Research report No. WES/100/01-91/005.
[13] Wolverton, J., Wolverton, B.C., Improving Indoor Air Quality Using Orchids and Bromeliads, *Plants for Clean Air Council,* 1991b, Research Report No. WES/100/12-91/006.
[14] Wolverton, B.C., Wolverton, J., Bioregenerative Life Support Systems for Energy-Efficient Buildings, in Proceedings Intl. Conf. Life support and Biospherics, 1992a, pp.117-126.
[15] Wolverton, J., Wolverton, B.C., Interior Plants and Their Role in Indoor Air Quality: An Overview, *Plants for Clean Air Council,* 1992b, Research Report No. WES/100/06-92/008.
[16] Ulrich,R.S., Visual landscape and psychological well-being, *Landscape Res.*, 1979, Vol.4, pp.17–23.
[17] Ulrich, R. S., Lundén, O., J. L. Eltinge Effects of exposure to nature and abstract pictures on patients recovering from heart surgery, *Paper presented at the Thirty-Third Meetings of the Society for Psychophysiological Research,* 1993, Vol.7.
[18] Hartig, T., Evans, G.W., Jamner, L.D., Davis, D.S., Garling, T., Tracking Restoration in Natural and Urban Field Settings, *J. Environ. Psychol.,* 2003, Vol.23, pp.109-123.
[19] Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., Nakashima, T., Ohira, H., Shirakawa, T., Psychological Effects of Forest Environments on Healthy Adults: Shinrin-yoku (forest-air bathing, walking) as a Possible Method of Stress Reduction, *Public Health*, 2007, Vol.121, No.1, pp.54-63.
[20] Lee, J., Park, B.J., Tsunetsugu, Y., Ohira, T., Kagawa, T., Miyazaki, Y., Effect of Forest Bathing on Physiological and Psychological Responses in Young Japanese Male Subjects?, *Public Health*, 2001, Vol.125, No.2, pp.93-100.
[21] Thompson, C.W., Roe, J., Aspinall, P., Mitchell, R., Clow, A., Miller, D., More Green Space is Linked to Less Stress in Deprived Communities: Evidence from Salivary Cortisol Patterns, *Landsc.Urban Plan,* 2012, Vol.105, pp.221-229.
[22] Tsurumi, T., Kuramashi, K., Managi, S., Determinants of Happiness: Environmental Degradation and Attachment to Nature. In: Managi, S. (Ed.), *the Economics of Biodiversity and Ecosystem Services,* Routledge, New York, USA. 2003.
[23] Ünlü, F., Yıldırım, K., Exploring the Knowledge Level of Interior Architecture and Environmental Design Students' on Indoor Air Pollutants, *Megaron,* 2015, Vol.10, No.4, pp.622-636.
[24] Benvenuti, S., Malandrin, V., Pardossi A. Germination Ecology of Wild Living Walls for Sustainable Vertical Garden in Urban

Environment, *Scientia Horticulturae*, 2016, Vol.203, pp.185–191. http://ac.els-cdn.com/S0304423816301509/1-s2.0-S0304423816301509- main.pdf?_tid =1608d898-6ebf-11e6-8083-00000aab0f6c&acdnat=1472567946_d1ca33eb418a7 6e4 c03e1b75 568f74d7

[25] Levin, H., Best Sustainable Indoor Air Quality Practices in Commercial Buildings in Environmental Building News, *Third Annual Green Buildings Conference and Exhibition*, 17-19 November 1996, San Diego, California, pp. 1-23. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.690.7564

[26] Ünlü, F., Yıldırım, K., Exploring the Knowledge Level of Interior Architecture and Environmental Design Students' on Indoor Air Pollutants, *Megaron,* 2015, Vol.10, No.4, pp.622-636.

[27] Kim, Y.M., Harrad, S., Harrison, R.M., Concentrations and Sources of VOCs in Urban Domestic and Public Microenvironments, *Environ. Sci. Tech.,* 2001, Vol.35, pp.997–1004.

[28] Lee, S.-C., Guo, H., Li, W.-M., Chan, L.-Y., Inter-comparison of Air Pollutant Concentrations in Different Indoor Environments in Hong Kong, *Atm. Env.*, 2002, Vol.36, pp.1929–1940.

[29] Loh, M.M., Houseman, E.A., Gray, G.M., Levy, J.I., Spengler, J.D., Bennet, D.H., Measured Concentrations of VOCs in Several Non-residential Microenvironments in the United States, *Environ. Sci. Technol.*, 2006, Vol.40, pp.6903– 6911.

[30] Eklund, B. M., Burkes, S., Morris, P., Mosconi, L., Spatial and Temporal Variability in VOC Levels within a Commercial Retail Building. *Indoor Air,* 2008, Vol.18, pp.365–374.

[31] Levin, H., Building Materials and Indoor Air Quality, *Occupational Medicine: State of the Art Reviews,*1989, Vol.4, pp.667–693.

[32] Strobridge, J.R., Black, M.S., Volatile Organic Compounds and Particle Emission Rates and Predicted Air Concentrations Related to Movable Partitions and Office Furniture, *Healthy Buildings '91, ASHRAE,* Atlanta, 1991, pp.292–298.

[33] Knoppel, H., Schauenburg, H., Screening of Household Products for the Emission of Volatile Organic Compounds, *Environment International,* 1989, Vol.15, pp.413–418.

[34] Sack, T.M., Steele, D.H., Hammerstrom, K., Remmers, J., A Survey of Household Products for Volatile Organic Compounds, *Atmospheric Environment,* 1992, Vol.26A, pp.1063–1070.

[35] Wallace, L.A., Pellizari, E.D., Leaderer, B.P., Zelon, H., Sheldon, L., Emissions of Volatile Organic Compounds from Building Materials and Consumer Products. *Atmospheric Environment*, 1987, Vol.21, pp.385–393.

[36] Wallace, L.A., Personal Exposures to 25 Volatile Organic Compounds; EPAS 1987 TEAM study in Los Angeles, *California Toxicology and Industrial Health*, 1991, Vol.516, No.7, pp.203– 208.

[37] Lee, C.W., Dai, Y.T, Chien, C.H., Hsu, D.J., Characteristics and Health Impacts of Volatile Organic Compounds in Photocopy Centers, *Environ. Res.,* 2006, Vol.100, No.2, pp.139–149.

[38] Liu, Z., Ye, W., Little, J.C., Predicting Emissions of Volatile and Semivolatile Organic Compounds from Building Materials: A Review, *Building and Environment*, 2013, Vol.64, pp.7-25. http://ac.els-cdn.com/S0360132313000619/1-s2.0-S0360132313000619-main.pdf?_tid= fcb21666-6e91-11e6-a68f-00000aacb361&acdnat=1472548577_42822c268d5bca8f38 e0e42536a95d48

[39] Wolverton BC, Kozaburo T., *Plants: Why You Can't Live without Them*, Roli Books, New Delhi, 2010.

[40] EU. Critical Appraisal of the Settling and Implementation of Indoor Exposure Limits in the EU, In: The INDEX Project, Final Report, 2005.

[41] Katsoyiannis, A., Leva, P., Kotzias, D., Determination of Volatile Organic Compounds Emitted from Household Products, The case of velvet carpets, *Fresenius Environ. Bull.*, 2006, Vol.15, No.8b, pp.943–949.

[42] Harbin, K., Maybe a Little Office Greenery Will Help Heal Your 'Sick Building', *The Enterprise - Utah's Business Journal*, December 22-28, 2014. http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=10&sid=ddf9e455-fe7f-49ad-9460-83dece07bf9e%40sessionmgr4008&hid=4109

[43] [NIOSH] National Institute for Occupational Safety and Health, Pocket guide to chemical hazards, Department of Health and Human Services. Centers for Disease Control and Prevention (CDC), 2007, No. 2005, pp.149.

[44] Missia, D.A. , E. Demetrioub, N. Michaelb, E.I. Tolisa, J.G. Bartzisa, Indoor Exposure from Building Materials: A Field Study,

Atmospheric Environment, 2010, Vol.44, pp.4388-4395. http://ac.els-cdn.com/S1352231010006291/1-s2.0-S1352231010006291-main.pdf?_tid= ee8e92b6-6e92-11e6-ae87-00000aab0f6b&acdnat=1472548982_bf1573a2f222d387 f5606 2fb59 8261f5

[45] WHO, International Agency for Research on Cancer, Monographs on the Evaluation of the Carcinogenic Risks to Human, 1999, Vol.71. https://monographs.iarc.fr/ENG/Monographs/vol71/mono71.pdf

[46] Sriprapat, W., Suksabye, P., Areephak, S., Klantup, P., Waraha, A., Sawattan, A. Thiravetyan , P., Uptake of Toluene and Ethylbenzene by Plants: Removal of Volatile Indoor Air Contaminants, *Ecotoxicology and Environmental Safety*, 2014, Vol.102, pp.147–151.

[47] Tanaka-Kagawa T, Jinno H, Furukawa Y, Nishimura T., Volatile Organic Compounds (VOCs) Emitted from Furniture and Electrical Appliances, *Kokuritsu Iyakuhin Shokuhin Eisei Kenkyusho Hokoku,* 2010, Vol.128, 71-7.

[48] Ohura T, Amagi T, Shen XL, Zhang P, Zhu L., Comperative Study on Indoor Air Quality in Japan and China: Characteristics of Residential Indoor and Outdoor VOCs, *Atmos Environ,* 2009, Vol.43, pp.6352-59. http://www.sciencedirect.com/science/article/pii/S1352231009007973

[49] Lohr, V.I., The Contribution of Interior Plants to Relative Humidity in an Office. In: Diane Relf (ed.). *The Role of Horticulture in Human Well-being and Social Development*, 1992, pp.117-119, Timber Press, Portland, OR. Reprinted in: Interiorscape, 1995, Vol.14, No.2, pp.50-53.

[50] Homesb.C., Wolverton, Rebecca C., McDonald, E.A., Watkins, Jr., Foliage Plants For Removing Indoor Air Pollutants From Energy-Efficient, Economic Botany, 1984, pp. 224-228.

[51] Aydogan, A., Montoya, L.D., Formaldehyde Removal by Common Indoor Plant Species and Various Growing Media, *Atmospheric Environment*, 2011, Vol.452, pp.675-2682. http://www.sciencedirect.com/science/article/pii/S1352231011002263

[52] Alexandri, E., Jones, P., Temperature Decreases in an Urban Canyon due to Green Walls and Green Roofs in Diverse Climates. Build, *Environ*, 2008, Vol.43, No.4, pp.480–493

[53] http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=8&sid=885ca53e-dece-421c-9d92-d108fc9f9766%40sessionmgr106&hi d=115

[54] Wong, N., Tan, A., Tan, P., Sia, A., Wong, N. Perception Studies of Vertical Greenery Systems in Singapore, Journal of Urban Planning and Development, 2010, pp.330-338. http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29UP.1943-5444.0000034

[55] Safikhani, T., Abdullah, A.M., Ossen, D.R., Baharvand, M., A Review Of Energy Characteristic Of Vertical Greenery Systems. *Renewable and Sustainable Energy Reviews*, 2014, Vol.40, pp.450-462. http://www.sciencedirect.com/science/article/pii/S1364032114006182

[56] Wolverton BC, Kozaburo T., *Plants: Why You Can't Live without Them*, Roli Books, New Delhi, 2010.

[57] NTP. Final Report on Carcinogens, Background Document for Formaldehyde, *Research Triangle Park, NC:National Toxicology Program*, 2010. http://tinyurl.com/3hym4jp

[58] Xu Z, Wang L,, Hou H., Formaldehyde Removal by Potted Plant-Soil Systems, Journal of Hazard Mater, 2011, Vol.192, No.1, pp.314–318. http://dx.doi.org/10.1016/j

[59] Yang, DS., Pennisi, SV., Son, KC., Kays, SJ., Screening Indoor Plants for Volatile Organic Pollutant Removal Efficiency, HortScience 2009 Vol.44, No.5, pp.1377-1381.

[60] Yıldırım, K., Bitkilerin İç Mekân Kirleticileri Üzerindeki Etkileri, *İçmimar Dergisi*, 2013, No.28, pp.107-115.

[61] Sriprapat W., Boraphech P., Thiravetyan P., Factors Affecting Xylene-Contaminated Air Removal by the Ornamental Plant Zamioculcas Zamiifolia, Environ Sci Pollut Res Int., 2014 Vol.21, No.4, pp.2603-10.

[62] Hindle, R. L., A Vertical Garden: Origins of the Vegetation-Bearing Architectonic Structure and System (1938), *Studies in the History of Gardens & Designed Landscapes*, 2012, Vol.32, No.2, pp.99-110. http://www.tandfonline.com/doi/pdf/10.1080/14601176.2011.653535?needAccess=true

[63] http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=8&sid=885ca53e-dece-421c-9d92-d108fc 9f9766%40sessionmgr106&hid=115

[64] Krathwohl, D. R., *Methods of educational & social science research: An integrated approach*, Addison-Wesley Educational Publishers, Inc., United States, 1997.

[65] Schuman, H., Presser, S., The Open and Closed Question, *American Sociological Review*, 1979, Vol.44, No.5, pp.692–712.
[66] Yates, F., Contingency Table Involving Small Numbers and the $\chi 2$ Test, *Journal of the Royal Statistical Society (Supplement)*, 1934, No.1, pp.217-235.