INTERNATIONAL SCIENTIFIC CONFERENCE

PEOPLE, BUILDINGS AND ENVIRONMENT 2012

CONFERENCE PROCEEDINGS

Lednice, November 7-9, 2012, Czech Republic

Published: BRNO UNIVERSITY OF TECHNOLOGY, FACULTY OF CIVIL ENGINEERING
Printed: BRNO UNIVERSITY OF TECHNOLOGY, FACULTY OF CIVIL ENGINEERING

Edited by:

Tomáš Hanák, *Editor-in-chief*
Petra Adlofová, Lucie Kozumplíková, Michaela Peštuková, *Editors*

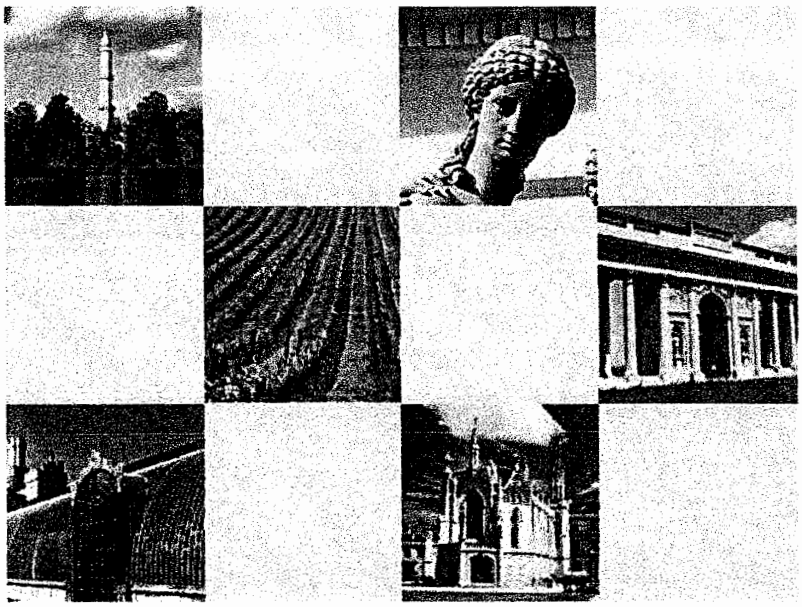
Published in 2012

First edition

ISBN 978-80-214-4618-2

INTERNATIONAL SCIENTIFIC CONFERENCE

PEOPLE, BUILDINGS AND ENVIRONMENT 2012



Lednice, November 7-9, 2012, Czech Republic

organized by

BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF CIVIL ENGINEERING
INSTITUTE OF STRUCTURAL ECONOMICS AND MANAGEMENT
INSTITUTE OF WATER STRUCTURES

Lesnická a dřevařská fakulta

MENDEL UNIVERSITY IN BRNO
FACULTY OF FORESTRY AND WOOD TECHNOLOGY
DEPARTMENT OF LANDSCAPE FORMATION AND PROTECTION

Papers have been double-blind peer reviewed before final submission to the conference. Initially, paper abstracts were read and selected by the conference Scientific Committee as possible papers for the conference.

PBE2012's Publication Ethics and Publication Malpractice Statement is based, in large part, on the guidelines and standards developed by the Committee on Publication Ethics (COPE). Publication Ethics and Publication Malpractice Statement defines responsibilities of authors, reviewers, members of Scientific Committee and editors.

Many thanks to the reviewers who helped ensure the quality of the published manuscripts.

Print version with full text papers ISBN: 978-80-214-4618-2
Online version with full text papers ISBN: 978-80-214-4617-5

Conference web page: www.fce.vutbr.cz/ekr/pbe

SCIENTIFIC COMMITTEE

Assoc. Prof. **Jana Korytárová**, M.Sc. Ph.D., *President,*
Brno University of Technology, Czech Republic

Assoc. Prof. **Magdaléna Bálintová**, M.Sc. Ph.D.,
Technical University of Košice, Slovakia

Prof. **Boriss Gjunsburgs**, M.Sc. Ph.D.,
Riga Technical University, Latvia

Dr. **Miklós Hajdu**, M.Sc. Ph.D.,
University of Szent István, Hungary

Assoc. Prof. **Vít Hromádka**, M.Sc. PhD.,
Brno University of Technology, Czech Republic

Prof. **Koloman Ivanička**, M.Sc. PhD.,
Slovak University of Technology, Slovakia

Assoc. Prof. **Miloš Knežević**, M.Sc. Ph.D.,
University of Montenegro, Montenegro

Assoc. Prof. **Leonora Marková**, M.Sc. Ph.D.,
Brno University of Technology, Czech Republic

Prof. **Vjeran Mlinarić**, M.Sc. Ph.D.,
University of Zagreb, Croatia

Assoc. Prof. **John-Paris Pantouvakis**, Ph.D.,
National Technical University of Athens, Greece

Prof. **Mladen Radujković**, M.Sc. Ph.D.,
University of Zagreb, Croatia

Dr. **Carles Serrat**, M.Sc. Ph.D.,
UPC-Barcelona TECH, Spain

Assoc. Prof. **Jana Šelih**, M.Sc. Ph.D.,
University of Ljubljana, Slovenia

Assoc. Prof. **Miloslav Šlezingr**, M.Sc.,
Mendel University in Brno, Czech Republic

Assoc. Prof. **Daniela Špirková**, M.Sc. PhD.,
Slovak University of Technology, Slovakia

Assoc. Prof. **Alena Tichá**, M.Sc. Ph.D.,
Brno University of Technology, Czech Republic

Prof. **Pavel Tomšík**, M.Sc. Ph.D.,
Mendel University in Brno, Czech Republic

Assoc. Prof. **Martina Zeleňáková**, M.Sc. Ph.D.,
Technical University of Košice, Slovakia

Assoc. Prof. **Maria Zúbková**, M.Sc. PhD.,
Slovak University of Technology, Slovakia

Prof. **Valentina Žileska-Pančovska**, M.Sc. Ph.D.,
SS.Cyril and Methodius University in Skopje, Macedonia

ORGANIZING COMMITTEE

Tomáš Hanák, Chairman
Brno University of Technology, Czech Republic

Petra Adlofová
Brno University of Technology, Czech Republic

Petr Aigel
Brno University of Technology, Czech Republic

Jitka Fialová
Mendel University in Brno, Czech Republic

Pavlína Havlasová
Brno University of Technology, Czech Republic

Ilona Kasalová
Brno University of Technology, Czech Republic

Lucie Kozumplíková
Brno University of Technology, Czech Republic

Jana Nováková
Brno University of Technology, Czech Republic

Petr Pelikán
Mendel University in Brno, Czech Republic

Michaela Peštuková
Brno University of Technology, Czech Republic

Kateřina Vymětalová
Brno University of Technology, Czech Republic

Miloš Waldhans
Brno University of Technology, Czech Republic

CONTENT

KEYNOTE LECTURES

SECTION I: CONSTRUCTION ECONOMICS AND MANAGEMENT

SECTION II: WATER MANAGEMENT AND WATER STRUCTURES

SECTION III: LANDSCAPE MANAGEMENT

SECTION IV: UNIVERSITY TEACHING AND LEARNING OF CIVIL ENGINEERING

INTERNATIONAL SCIENTIFIC CONFERENCE
PEOPLE BUILDINGS AND ENVIRONMENT 2012
7.-9. 11. 2012, LEDNICE, CZECH REPUBLIC

EARLY STUDY ON FACTS AND PERCEPTIONS OF INDOOR PLANTS AND INDOOR NOISE LEVELS

Christina Eviutami Mediastika[1], Floriberta Binarti[2], Laurensia Indah Murwani Yulianti[3]

Abstract

Two types of plants were used in a study to see employee perceptions and facts of plants in reducing indoor noise level, i.e. Sansevieria trifasciata and Scindapsus sp. Each type were planted in containers and placed inside cubicles of two offices. The noise levels were measured using sound level meters and taken in 3 periods, i.e. without plants, with Sansevieria, and with Scindapsus in place. Questionnaire surveys among employees and leaves' absorption coefficient (α) measurement were also conducted. Both leaves showed significant α at high sound frequencies, i.e. 0.6. But, the meters showed very insignificant noise difference before and after plantings, i.e. only 3 dB with no regard of plant types. Fluctuation of 3 dB is hardly noticed by human hearing instruments. Whilst, the surveys showed contradictory results, 60% (1st office) and 22% (2nd office) of employees agreed that noise level was lowered after plantings. These showed that indoor plants might create more pleasant environment for employees to feel undisturbed by noise, where actually the noise remained at similar levels.

Key words

Cubicle rooms, employee perception, indoor plants, noise levels.

To cite this paper: *C. E. Mediastika F. Binarti, L. I. M. Yulianti. Early Study on Facts and Perceptions of Indoor Plants and Indoor Noise Levels, In conference proceedings of People, Buildings and Environment 2012, an international scientific conference, Lednice, Czech Republic, 2012, p 710-718, ISBN: 978-80-214-4617-5.*

[1] Christina Eviutami Mediastika, PhD, Department of Architecture, Atma Jaya Yogyakarta University (AJYU), Jalan Babarsari 44, Yogyakarta, Indonesia 55281, utami@mail.uajy.ac.id
[2] Floriberta Binarti, Dipl.NDS.Arch, Department of Architecture, Atma Jaya Yogyakarta University (AJYU), Jalan Babarsari 44, Yogyakarta, Indonesia 5528 1, binarti@mail.uajy.ac.id
[3] Laurensia Indah Murwani Yulianti, MSc, Department of Techno-Biology, Atma Jaya Yogyakarta University (AJYU), Jalan Babarsari 44, Yogyakarta, Indonesia 5528 1, lindah@mail.uajy.ac.id

1 INTRODUCTION

The use of plants as elements of built environment and building design has long been known, especially within the last 30 years, where architect include plants in their design either for outdoor or indoor decorations. It is usually aimed to create aesthetic aspect of given conditions. Some are also to function as lungs to absorb pollution [1] and to create more comfortable microclimatic conditions [2]. Studies on the usage of greenery in the indoor environment with function to reduce indoor pollution have shown a prospective result [3,4]. Here, researchers suggest the use of particular type of indoor plants; i.e. those with little maintenance, such as ability to live with minimum sun exposure and water. One of the suggested is snake plant or in scientific named as Sansevieria trifasciata laurentii [5], which is a kind of robust plants.

Apart from capability of absorbing indoor pollutant, some people also believe that plants are capable of reducing the intrusion of outdoor noise into the interior space. However, some are still unconvinced [6]. This negative opinion is supported by theories which explain that plants has no capability on reducing noise based on the fact that plants has never become a complete solid and dense material as is required for noise insulation [7]. However, it is true that plants may absorb or impede noise propagation [8]. Hence, it is predicted that plants work better within indoor environment to overcome indoor background noise problem which level and vibration is lesser than those occur outdoor. Air and objects within indoor environment are also easier to control and usually are in steady condition that will minimise noise reduction affecting factors.

Open-plan office divided into numbers of cubicles was chosen as role model . Each cubicle in this office suffers from indoor background noise, since one cubicle cannot entirely block sound transmission from other cubicles. There are options to stop noise dispersion using absorbent linings, such as thick carpets, hanging ceilings and porous walls. Despite using these conventional materials, usage of indoor plants to lower indoor background noise in open-plan office is proposed here. It is expected that indoor plants will perform as absorbent linings and can be used either by itself or in conjunction with conventional absorbent linings. The use of indoor plants will also benefit in the improvement of indoor air [3] and to more general global warming issue. User opinions on noise levels before and after installation of greenery were also to be studied.

2 OBJECTIVE

The aim of this study is to see any positive correlations between user perceptions and facts regarding the use of indoor plants, particularly Sansevieria trifasciata laurentii and Scindapsus sp to reduce indoor background noise levels (qualitative aspects).

3 THEORETICAL APPROACH

Plants consist of leaves which has unique surface with stoma and delicate hair [9]. These are just similar to properties of material used to absorb sound, such as soft surface perforated panels. However, since stoma and hair are very delicate, it will only work for high frequency noise, i.e. noise that is not entitled of vibration. The small porous surfaces provide high frequency absorption [10]. A study by Costa [8], showed that particular indoor plants were capable of absorbing sound as shown by Table 1.

Tab. 1) Absorption Coefficient Provided by Particular Indoor Plants [8]

Absorption Coefficients						
Plant species	**Sound Frequency (Hz)**					
	125	**250**	**500**	**1000**	**2000**	**4000**
Ficus benjamina	0.06	0.06	0.10	0.19	0.22	0.57
Howea forsteriana	0.21	0.11	0.09	0.22	0.11	0.08
Dracaena fragrans	0.13	0.14	0.12	0.12	0.16	0.11
Spathiphyllum wallisii	0.09	0.07	0.08	0.13	0.22	0.44
Dracaena marginata	0.13	0.03	0.16	0.08	0.14	0.47
Schefflera arboricola	-	0.13	0.06	0.22	0.23	0.47
Philodendron scandens	-	0.23	0.22	0.29	0.34	0.72

This research shows that plants are generally more efficient in absorbing high frequency sound. This is because sound at low frequencies are of longer wavelength [11] which could not be absorb by such tiny leaf and stoma. Leaf is also a non solid material which usually used to absorb sound of low frenquencies .

The plants studied by Costa showed promising absorption coefficient. However, they mostly request careful maintenance [12]. Ficus benjamina need to be kept in specific level of humidity and particular level of light so not to cause leaf turning yellow. Howea forsteriana also need careful watering and particular light level for growing. Both Draceana (fragrans and marginata) are robust plants, but they may grow more then 3 m tall, so it will only suit offices with high ceilings. Spathiphyllum wallisii need sufficient indirect light to borne its beautiful flower. Schefflera arboricola need careful maintenance, such as light, water and pruning. Philodendron scandens is a kind of climbing plants thus will need frames for further growing. It is not saying that all those kind of plants are not worth it to be utilized indoor, but there is another kind of plants which is more robust and almost free maintenance, which is called Sansevieria trifasciata (refer to Figure 1). Beside its robustness and minimum maintenance, unlike other plants that release CO_2 at night, this Sansiviera converts CO_2 into O_2 [13]. So it is safe to be kept within offices that expand their working period up to night time. There are about 600 types of Sansevieria around the world, but the most famous is Sansevieria trifasciata, which is also commonly known as snake plants. Its origin is Western Africa. There are some types of Sansiviera trifasciata (about 18 types), among the famous are laurentii, hahnii, and golden hahnii.

As a member of cactus plants family, Sansevieria trifasciata does not demand on water. Although originally comes from Western Africa, a region with abundance solar, Sansevieria trifasciata does not demand on excessive solar light. It can be put indoor, even in a remote area from transparent windows. Indeed, it does need to be placed outdoors for sun exposure, but this can be done merely once every week or once every two weeks at the longest [12]. Stiff leaves of Sansevieria trifasciata will not easily fade and change color so they will be charming most of the time. In particular, Sansevieria trifasciata laurentii has slim and tall posture; a perfect posture to block sound dispersion. As a comparison, Philodendron scandens was also planned to be studied here. The reason in using Philodendron scandens is because this offers greatest absorption coefficient among the measured plants as is shown by Table 1. It also does not require any specific indoor climatic condition unless frames for further growing. Leaves of Philodendron scandens which is thin, soft, and round shaped may also be compared to leaves of Sansevieria trifasciata which is thick, stiff and ribbon alike shaped.

However, within very limited natural resources, it was difficult to prepare the Philo, therefore, Scindapsus sp (refer to Figure 2) which has similar characteristic to those of Philo and widely available was then used to substitute.

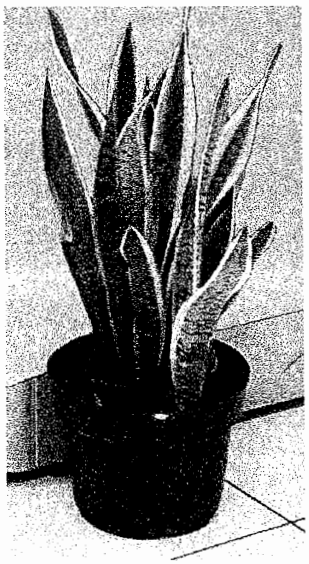


Fig. 1) Sanscvicria trifasciata laurentii

Fig. 2) Scindapsus sp

4 METHODOLOGY

The study was conducted as empirical study by field research, which is a comprehensive between qualitative and quantitative aspects. People working in two offices are the focus of this study. Type of offices to study is limited to open-plan office divided into numbers of cubicle, where one cubicle may suffer noise from adjacent or far cubicles. It is also limited to offices that do not use any absorbent linings such as carpets, or porous ceilings and walls. Administration office of Faculty of Engineering of Atma Jaya Yogyakarta University (AJYU,

refer to Figure 3) and Design Graphics dan Mechanical Engineering office of PT. Alstom Power Indonesia, Surabaya (refer to Figure 4) and their employees, were the focus of this study. Noise perception and expectation of these types of workers are to be analysed, in order to see the its correlation to indoor noise levels before and after installation of plants.

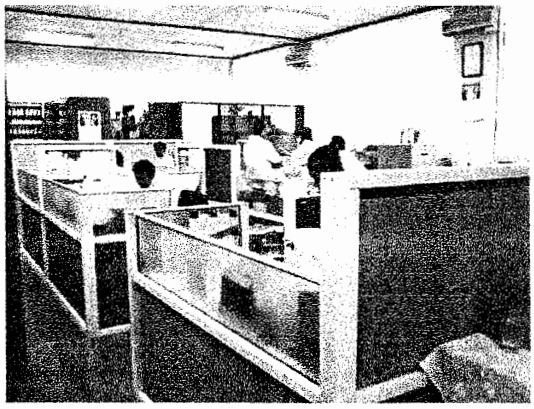


Fig. 3) Administration office of AJYU

Fig. 4) Design Graphics dan Mechanical Engineering office of PT. Alstom

At the first stage, existing noise levels within the two office were studied. The investigation processes in this level may be grouped as follows:

- Measurements of existing background noise levels.
- Data collection (questionnaire surveys and interviews) of employees perception and expectation on the existing background noise.
- Laboratory measurement of leaves' absorption coefficient.

At the second stage, Sansevieria trifasciata plants are placed in the offices. One medium container (contains of approximately 8 mature plants of 80 cm height, as in Figure 1) of Sansevieria trifasciata laurentii is placed in each cubicle. Minimum area of a cubicle in an office is 1,2 m^2 [14]. After placement of plants, measurements, questionnaire surveys and interviews were again conducted.

At the third stage, Sansevieria trifasciata laurentii was substituted by Scindapsus sp. One medium container (contains of approximately 80 cm height, as in Figure 2) of Scindapsus sp is placed in each cubicle. In AJYU office there were 10 employees stays in 10 cubicles, so

there were 10 containers of each type of plants placed for the entire office. Whilst in Alstom office, 34 containers of each type of plants to fit within 34 cubicles for 34 employees. From here, we could learn whether there is any indoor background noise reduction after placing this particular plants, and whether it is match to office employees perceptions and expectations.

5 QUESTIONNAIRE SURVEYS RESULT

All employees within the room of both AJYU and Alstom were respondents for interviews and questionnaire surveys. Both at AJYU and Alstom, 90% of the employees are male, which caused difficulty in describing whether there was any different opinion between male and female. Thus the gender factors were disregarded. Comprehensive answers of the questionnaire is presented in Table 2.

Tab. 2) Questionnaire Results

No.	Item	AJYU office	Alstom office
1.	Age	between 36 to 55 years of age	between 25 to 50 years of age
2.	Duration of employments in the offices	varies from under 1 year - over 5 years	varies from under 1 year - 3 years
3.	Opinion on the existing background noise levels	80% said 'fair' 20% said 'too much/over the standard'	75% said 'fair' 25% said 'too much/over the standard'
4.	Opinion on the disturbance levels	80% said 'no disturbance' 20% said 'sometimes difficult to focus on work'	78% said 'no disturbance' 22% said 'sometimes difficult to focus on work'
5.	Expectation of further conditions to the office room	80% suggested the room to be renovated 20% said nothing (abstain)	72% suggested the room to be renovated 28% said nothing (abstain)
6.	Basic knowledge on plants as noise reduction materials	50% knew about it 50% knew nothing	40% knew about it 60% knew nothing
7.	Further expectation on the use of plants to reduce indoor noise levels	70% believes plants will do the task 30% knew nothing	44% believes plants will do the task 56% knew nothing
8.	Part of plants that may reduce noise levels	60% said leaves 40% knew nothing	50% said leaves 50% knew nothing
9.	Plants creates better visualization	80% agreed 20% felt distracted	65% agreed 35% felt no difference
10.	Opinion on noise reduction	60% agreed on noise reduction after placement of plants 40% disagreed	22% agreed on noise reduction after placement of plants 78% disagreed
11.	Opinion on plants was reducing indoor noise levels (from those who agrres on item number10)	75% noise reduction was caused by plants 25% noise reduction was caused by other factors	73% noise reduction was caused by plants 27% noise reduction was caused by other factors

6 INDOOR NOISE LEVELS AND ABSORPTION COEFFICIENT OF LEAVES

Indoor background noise levels were collected in 3 groups of time using Sound Level Metres (SLM) DEKO – SL 130 digital. The SLM was set in an A-weighting network. The 3 groups, i.e. existing noise conditions, after installation of Sansevieria trifasciata laurentii, and after installation of Scindapsus sp. Each group of data collecting was conducted for 3working days during working hours. However, 30 minutes after the working hour starts and 30 minutes before the working hour ends were not recorded, considering non steady noise levels caused by transition time of employees entering and leaving the room. There were 3 different measurement positions within each office to collect the average background noise levels,

using 3 SLM. The collected data were then calculated into L_{eq} values. The L_{eq} represents equivalent background noise levels during 3 groups of time measurement and 3 days-each of groups. Since the data was recorded every second, there were thousands of values collected. Here, will only be reported the final data after calculated into L_{eq}. Both at AJYU and Alstom offices, there were no significant difference on noise levels between existing condition and after the use of Sansevieria trifasciata laurentii and Scindapsus sp. There was noise reduction after placement of plants which varies from 0,33 to 3,94 dBA. However, the difference between plants was so small, i.e. below 1 dBA. At Alstom, the condition was worse, i.e. no noise levels difference between existing and after use of plants (all differences was below 1 dBA).

On one hand, the insignificant noise levels differences in both offices showed that there was no impact on using indoor plants to reduce indoor noise. On the other hand, the laboratory measurement of leaves' absorption coefficient using impedance tube, showed a promising result, especially for frequency of 2000 Hz onwards as is shown by Table 3.

Tab. 3) Absorption Coefficient of Sansevieria and Scindapsus leaves

Frequency Band	Sansevieria (α_1)	Scindapsus (α_2)
250	0.156	0.137
315	0.095	0.125
400	0.166	0.182
500	0.228	0.242
630	0.306	0.261
800	0.195	0.216
1000	0.210	0.301
1250	0.251	0.417
1600	0.261	0.275
2000	0.411	0.633
2500	0.309	0.300
3150	0.617	0.539
4000	0.493	0.680
5000	0.477	0.531

Table 3 shows that leaves with their delicate hair and stoma absorb sound better at high frequencies, as was reported by Costa [8] and Harris [10], that small porous surfaces provide high frequency absorption. However, this was not correlate to the findings that the use of plants has insignificant effect on indoor noise reduction, which means leaves barely absorb noise. This might means that the indoor noise of the two offices were mostly of low frequencies or the number of containers of plants should be increased. The increase of plants may not be a good option since some respondents have said to be distracted by placement of plants.

7 CONCLUSION AND RECOMMENDATION

From the interview and questionnaire collected, we learn that although major respondents quote that indoor noise levels can be accepted, they were still expecting on room renovation to improve indoor noise levels quality. There was noise levels difference between before and after the placement of plants, and between the use of Sansevieria and Scindapsus. However, these are too small to be noticed by human hearing instruments [15]. This means that employee opinions of plants reducing indoor noise (60% of AJYU office and 22 % of Alstom

office) were only a perception which might be supported by their prior knowledge on plants capabilities to reduce pollution including noise.

From this study we may learn that people opinion on the use of plants were masking by their prior knowledge which is actually did not correlate to the facts showed by field measurements of the indoor noise levels. According to leaves' absorption coefficient measurement, the use of plants to absorb sound is recommended for higher frequencies. This correlate to that of Costa [8] and thus for further study, the indoor noise frequencies of particular room need to be studied prior to the use of plants.

Acknowledgement

The authors would like to thank Directorate Generale of Higher Education Learning of Ministry of Education of Republic of Indonesia for providing full financial support for this research.

REFERENCES

[1] Kusminingrum, Nani, Pengaruh Tanaman Jalan terhadap Baku Mutu Lingkungan, *Unpublished Research Report, Research Unit of Ministry of Public Works*, Republic of Indonesia, year of 1997/1998.

[2] Velesan, Mariane and Miguel Aloysio Sattler, Green Walls and Their Contribution to Environmental Comfort: Environmental Perception in a Residential Building, *Proceedings of 25th Conference on Passive and Low Energy Architecture*, Dublin, October 2008.

[3] Bonem, ML and Scheff PA, Deposition of Nitrogen Dioxide to Porous Biological Surfaces, *Proceedings of IAQ Conference The Human Equation: Health and Comfort*, 1989.

[4] Mediastika, CE, the Use of Fencing Plants to Reduce Particulate Matter Pollution into Indoor Environment, National Accredited *Journals "Dimensi Arsitektur"*, Surabaya Indonesia, December 2002.

[5] Mediastika, CE, et al., Perceptions And Facts On The Usage Of Indoor Plants To Eliminate Indoor Background Noise In Open-Plan Offices, *Unpublishded Research Report, Hibah Kompetensi Scheme* year of 2010/2011.

[6] *How to Make Sound Proof Fence* (URL: http://forum.doityourself.com/fences-gates/201981-how-make-sound-proof-fence.html).

[7] Freeborn and SW. Turner, Environmental Noise Vibration, *Noise Control in the Built Environment*, edited by John Roberts and Diane Fairhall, Gower Technical, US, 1988/1989, pp.54, 60 ISBN 978-0566-09001-1.

[8] Costa, P., and RW James, "Environmental Engineering Benefits of Plants", *Workplace Comfort Forum Seminar*, South Bank University, London, November 1995, pp. 7-8.

[9] Fahn, A., *Plant Anatomy*, Pergamon Press, England, 1990, pp. 208-248 ISBN 978-0080-37490-.

[10] Harris, Cyril M. , Acoustical Properties of Carpets, *Journal Acoustical Society of America*, Volume 27, Issue 6, pp. 1077-1082.

[11] White, R.G. and J.G. Walker, *Noise and Vibration*, Ellis Horwood Ltd., England, 1982, pp. 389-399 ISBN 0-85312-502-3.

[12] *How to Take Care Plants* (URL: http://www.plant-care.com).

[13] Wolverton, BC, *How to Grow Fresh Air: 50 House Plants that Purify Your Home or Office*, Penguin Book, 2008 ISBN 978-0297-84477-8.

[14] Neufert, Ernst, et. al, *Architect Data*, 3rd edition, Blackwell Publishing, 2002 ISBN 978-4051-9253-8.

[15] Mediastika, C.E., *Akustika Bangunan*, Penerbit Erlangga, Indonesia, 2005 ISBN 979-781-053-4.