The Level of 2-Methylbutane and Toluene Exposure in New Buildings: Can Adding Indoor Potted Plants Reduce Exposure?

by

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An Honors Thesis

submitted in partial fulfillment of the requirements

for the Honors Certificate

to

The University Honors Program

of

The University of Alabama in Huntsville

Date: 25 April 2014

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Background Negative health effects related to excessive exposure to indoor air pollutants, such as volatile organic compounds (VOCs), is a cause of concern. With individuals spending the majority of time inside sealed buildings, it is important to research efficient ways to reduce indoor air pollutants, in turn, improving overall health.

Methods Alternative methods to decrease levels of indoor VOCs, such as phytoremediation, could improve indoor air quality efficiently and cost effectively. This study was designed to discover the level of VOCs, specifically 2-methylbutane and toluene, present in four offices- before and after the addition of plants.

Results The results of this study showed that after the addition of plants, a reduction in 2-methylbutane levels was observed in two out of four ‘post-plant’ measurements and a reduction in toluene levels was observed in three out of four ‘post-plant’ measurements.

Conclusion Overall, reduction of these VOC levels after the addition of plants was observed in five out of the eight ‘post-plant’ measurements. Therefore, phytoremediation may be an effective way of reducing indoor air pollution.

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Acknowledgements

I would like to express my deepest gratitude to Dr. Azita Amiri and Dr. Ellise Adams for their excellent guidance, encouragement, patience, and support throughout this journey. This research would not have been achievable without them. Sincere appreciation is also given to Dean Faye Raines and Sigma Theta Tau - Beta Phi Chapter for their financial contributions and to Kelly Vazquez for assistance with data collection.

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The Level of 2-Methylbutane and Toluene Exposure in New Buildings: Can Adding Indoor Potted Plants Reduce Exposure?

According to Florence Nightingale, the connection between health and the dwelling of the population is one of the most important that exists (Lowery, 1991). Nightingale was a statistician and pioneer of nursing, who developed Nightingale's Environmental Theory. This theory focuses on the health of the home and community, as critical components of an individual's health; connecting the inter-relationship of a healthful environment with nursing (James, 2011). Concerns about poor indoor air quality have steadily increased since the early 1950's when correlations between indoor air pollution, allergies, and other chronic illnesses were first recognized (Randolph, & Ralph, 1980; Weschler, 2009). Today, indoor air pollution has resulted from types of building materials (United States Environmental Protection Agency [EPA], 2011, 2012) and the tight-sealing of buildings to increase their energy efficiency, leading to an unintended consequence, deterioration of indoor air quality (Nelson & Wolverton, 2011). According to Barro, Regueiro, Llompart, and Garcia-Jares (2009), VOCs comprise an important group of chemicals that evaporate easily at room temperature and are commonly present in indoor air. On average, Americans spend about 90 percent or more of their time indoors where levels of some pollutants may be two to five times higher, and occasionally more than 100 times greater than outdoor levels (U.S. EPA, 1993). Given that individuals spend the majority of their time indoors, it is critical to improve indoor air quality via decreasing VOC levels, to improve the health of the population. Nurses are advocates for the healthy lifestyle of individuals, families and communities, therefore, understanding the level of indoor air pollutants, such as 2-methylbutane and toluene and the ways reduce exposure is important.

Purpose

The purpose of this study was to determine the levels of 2-methylbutane and toluene in office spaces and to measure the effect of potted plants on reducing the levels of these two chemicals. Numerous research studies have been conducted in a variety of methods including laboratories and controlled atmospheres to measure the concentration of VOC uptake via plants (Kim, Kil, Song, Yoo, Son, & Kays, 2008; Sriprapat et al., 2014) and the emission rate and concentration of VOCs from multiple sources (Yan, Zhang, & Wang, 2009). This field study was conducted in faculty offices to observe the overall level of indoor air pollution before and after the addition of plants. The offices were not modified for this study; faculty still occupied them.

Review of Literature

Reduction Techniques

A variety of conventional methods exist to reduce the amount of VOCs in indoor environments, some of which can be inefficient or even expensive. These conventional mechanisms for VOC removal include adsorption, thermal or catalytic combustion, photocatalytic methods, and biological methods (Sriprapat & Thiravetyan, 2013). However, some of these available techniques prove to be ineffective in treating polluted indoor air due to difficulties linked to measuring the very low concentrations (micrograms per cubic meter range) (Guieysse, Hort, Platel, Munoz, Ondarts, & Revah, 2008). Therefore, further research needs to be conducted to identify alternative methods to clean and circulate the air inside affected buildings (Sriprapat & Thiravetyan, 2013). Phytoremediation is an alternative method for treating VOC contaminated air (Sriprapat et al., 2014). “Recently phytoremediation, using plants to remove toxins from air, has been proposed as an efficient and cost-effective way to improve indoor air quality" (Sriprapat & Thiravetyan, 2013, p. 1). It was Wolverton and Wolverton (1996) who stated, "since planet earth's clean air originates from living, green plants, the concept of placing houseplants inside tightly sealed buildings to purify and revitalize indoor air has a scientific basis" (p. 99).

According to Wolverton and Wolverton (1992, 1993), more than fifty interior plants have been tested in sealed experimental chambers for their effectiveness in removal of certain commonly found VOCs. The National Aeronautics and Space Administration (NASA) has been involved with numerous studies using different plants, soils and hydroculture to remove VOCs from enclosed spaces (Nelson & Wolverton, 2011; Wolverton, 1996). In a study conducted by NASA Wolverton, (2009), "interior foliage plants, which thrive in the low-light conditions of the indoor environment, were placed throughout the living quarters to evaluate their ability to remove the buildup of VOCs that were off-gassing (VOCs emitting off of materials) from a newly constructed and furnished facility" (p. 3). Mass spectrometer/gas chromatograph analyses showed nearly all VOCs had been removed (Wolverton, 2009). A field study by Wood, et al. (2006), found when total VOC loads in the air of reference offices exceeded 100 parts per billion, concentrations of VOCs were greatly reduced from 50–75% in the presence of any of the three potted-plant regimes trialed.

It has been previously demonstrated that VOC removal is due to biological action of plants and microorganisms (Aydogen & Montoya, 2011). Once absorbed by the leaves, VOCs such as toluene are typically converted to organic amino acids (Kim, Kil, Song, Yoo, Son & Kays, 2008). In addition to plant leaves, certain microorganisms found in the growing media of indoor potted plants remove VOCs, even when the plant is removed from the media. Also, reduction of VOCs can be greater during the day or night, depending on the species of plant (Kim, Kil, Song, Yoo, Son & Kays, 2008). Research has been conducted to identify a deeper understanding of microbial activities and the mechanisms of substrate uptake at trace concentrations (Guieysse et al., 2008), and the most efficient plant species and plant part, for removing volatile indoor air pollutants (Kim, Kil, Song, Yoo, Son & Kays, 2008; Sriprapat et al., 2014). In addition to removing VOCs from indoor air, studies state that plants have shown to increase indoor relative humidity, thus increasing comfort, improved productivity and wellbeing, and be beneficial for mental health (Aydogan & Montoya, 2011).

Health Effects

Indoor contaminants, such as VOCs, in air affect human health as evidenced by the problems of multiple chemical sensitivity and sick building syndrome (Kagi, Fujii, Tamura, & Namiki, 2009), also known as building-related illness (Wood, 2006). It is not surprising that the Environmental Protection Agency (EPA) ranks indoor air pollution among the top five threats to human health (Wolverton, 2009). Exposure to low levels of indoor VOCs, such as 2-methylbutane and toluene, can cause adverse health effects. Negative health effects related to low levels of exposure to 2-methylbutane and toluene include: headaches, sleepiness, impaired ability to think, confusion, weakness, memory loss, nausea (Agency for Toxic Substances and Disease Registry [ATSDR], 2000) and may be asymptomatic (Wolkoff, 2013). Long-term exposure to high levels of these VOCs have similar health effects, as well as more serious ones including possible damage to the kidney and central nervous system (ATSDR, 2000). However, all adverse health effects related to long term exposure to low levels of these VOCs are still not fully known.

Sources of Volatile Organic Compounds

Poor indoor air quality has been attributed to factors including airtight buildings, changes in building materials and consumer products, poor ventilation, and poor moisture control (Aydogen & Montoya, 2011). These factors have contributed to a renewed interest in green building practices. According to Barro, Regueiro, Llompart, & Garcia-Jares (2009), VOC sources range from paint, plastics and building materials to pesticides and flame retardants. Tightly sealed environments, from office buildings to spacecraft, can have hundreds or even thousands of potential air pollutants, depending on the materials and equipment enclosed (Nelson & Wolverton, 2011). Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the area (Barro, Regueiro, Llompart, & Garcia-Jares, 2009). Primary emissions of VOCs from building materials, furniture, and equipment are recognized as one of the main problems affecting indoor air quality (Qian, Zhang, Little, & Wang, 2007). Secondary emissions of VOCs occur overtime from physical and chemical deterioration (Wolkoff & Nielsen, 2001) and chemical transformation related to exposure to sunlight, infrared light or ultraviolent (UV) irradiation (Kagi, Fujii, Tamura, & Namiki, 2009). When VOC concentration in the material is higher than VOC concentration in the room air, VOC diffuses through material to reach the material surface (Huang & Haghighat, 2003).

Summary of Review of Literature

Studies show that low-light requiring houseplants can influence removal rates of indoor VOCs. Adverse health effects related to poor indoor air quality (Wolkoff, 2013), are concerning. Therefore, sources of VOCs (Qian, Zhang, Little & Wang, 2007), and ways to remove them (Wolverton, 2009), are being researched. With these facts known, this study was designed to answer the research question: What are the levels of 2-methylbutane and toluene exposure in new buildings and old buildings: can adding indoor potted plants reduce exposure?

Materials and Methods

Study Design and Setting

This was a pilot one group pretest-posttest field study conducted at the University of Alabama in Huntsville, designed to measure the VOCs: 2-methylbutane and toluene. Four offices were used in this study. Office one and two, a newer building built in 2008 and office three and four, an older building built in1976. The two offices in the newer building measure approximately 20x20 feet. Each office has one big window. Both offices contain; one L-shaped desk with shelves on top, two book cases, two filing cabinets, two chairs, one computer, and a variety of office supplies. The two offices in the older building measure approximately 20x20 feet. Each office has one big window. The older building is located beside the construction site of a new building/addition.

Monitor Devices

The level of 2-methylbutane and toluene were measured using the Full Scan Organic Vapor Monitor from Advanced Chemical Sensors, Inc. (ACS). This monitor can detect over 100 different VOCs (see Appendix A for the list of VOCs). ACS monitors are sealed in an air-tight envelope that can be resealed after use and mailed for analysis (see Appendix B for more information about monitors used in this study).   Air diffuses through a micro-porous membrane and collects vapor on special prepared adsorbents inside the monitoring badge (Advanced Chemical Sensors, 2014). One VOC monitor was placed in each of the four offices at three separate times during this study.

Plants

According to Wolverton and Wolverton (1996), decrease in the level of airborne microbes was found when plants such as; Rubber Fig *(Ficus elastica),* Dumb Cane *(Dieffenbachia)* and Golden Pothos (*Epipremnum aureum*), *w*ere added to indoor spaces. The study by Wolverton and Wolverton (1996) served as a basis for selecting the plant species to use in this study. Each species of plant was added to all four offices. An additional Golden Pothos was placed in each of the four offices, three days after the initial placement of the aforementioned plants, due to cold weather damaging the Dumb Cane.

Study Procedure

This study began in January, 2014 and ended in March, 2014. A total of 12 monitors (three sets of four) and 16 plants were used. To serve as a control group, initial 'pre-plant' levels were measured in all four offices. Initial levels were measured in each office via one Full Scan Organic Vapor Monitor. Monitors were placed on top of a shelf, four feet from the ceiling, in all four offices and were left undisturbed in each of the four offices for 120 hours, per instructions from Advanced Chemical Sensors, Inc.

At their respective times, each monitor was collected and sealed in the air-tight envelopes provided by ACS. The VOC monitors were mailed to ACS for analysis. Results were then mailed or emailed back after analysis was completed.

Addition of plants. After measuring initial 'pre-plant' levels, plants were added. The first addition of plants to offices included one of each of the aforementioned species. Each species of plant was placed in all four offices, and left over the weekend. Upon returning, the Dumb Cane *(Dieffenbachia)* was damaged over the weekend, due to cold weather. An additional

Golden Pothos (*Epipremnum aureum*) was placed in each office to make up for the damaged Dumb Cane. Throughout the duration of this study, one Rubber Fig *(Ficus elastica)*, one Dumb Cane, and two Golden Pothos were used in the offices. Office one had two Golden Pothos and one Rubber Fig , which were placed on top of the desk shelf, about 4 feet from the ceiling. The Dumb Cane was placed on the window seal, about 4 feet from the ground. In office two, two Golden Pothos were placed on top of the desk shelf, about 4 feet from the ceiling. One Rubber Fig was placed on the ground beside a book case and chair and one Dumb Cane was placed on the window seal, about four feet from the ground. Office three had two Golden Pothos, placed on the ground under the window. In addition, one Rubber Fig placed on the floor beside a book case and a Dumb Cane placed on a filing cabinet in office three. Office four had two Golden Pothos placed on a desk, one Rubber Fig, placed on the floor under the window, and a Dumb Cane placed on a filing cabinet. The plants remained in this placement throughout the duration of the study and were cared for once a week.

Four week measurement. The plants remained in all four offices for four weeks. After four weeks, a ‘post-plant’ level was measured while the plants remained in the offices. Levels were measured using one organic vapor monitor in all four offices. The previous method was used for placement and collection of the second set of four monitors.

Six week measurement. The plants remained in the offices for a total of six weeks. After six weeks, the last set of ‘post-plant’ levels were measured using one organic vapor monitor in all four offices. The previous method was used for placement and collection of the third set of four monitors.

VOC unit of concentration information. The laboratory measures the milligrams (mg) of each chemical collected during the exposure of the monitoring badge. The collection rate for each chemical (milliliters/minute) is known from actual calibration tests. When the user provides the exposure time (120 hours for VOC monitor), then it is a simple algebraic calculation to give the concentration in milligrams/cubic meter. The parts per billion (ppb) is related to the milligrams/cubic meter for each chemical (Advanced Chemical Sensors, Inc., 2014).

Organization of results. Results were recorded in Microsoft Excel. Charts and bar graphs were created, using Excel, to show the relationship between all three data sets. Four charts representing offices one, two, three, and four were created. Each chart had three sections labeled; initial ‘pre-plant’ levels, four week ‘post-plant’ levels and six week ‘post- plant’ levels. Note: VOCs not analyzed in this study are included in the analysis report (see Appendices C-F for charts). Two bar graphs were created; one representing the newer building and one representing the older building. Both bar graphs had three sections labeled; initial ‘pre-plant’ levels, four week ‘post-plant’ levels and six week ‘post- plant’ levels. Results from offices one and two, in the newer building, were averaged and placed in the respective section. Results from offices three and four, in the older building, were averaged and placed in the respective section. The bar graphs show the mean of identical chemicals found in each buildings offices (see Appendices G and H for bar graphs).

Results

This study focused on 2-methylbutane and toluene levels (Figure 1 and 2). The mean of 2-methylbutane and toluene were calculated for offices one and two in the newer building. Levels were separated by their measurement title; initial, four week and six week. The same process was used for calculating the mean levels for the older building.

Figure 1- Level of 2-mehtylbutane and toluene levels before and after adding plants (week 4 and week 6) in the newer building.

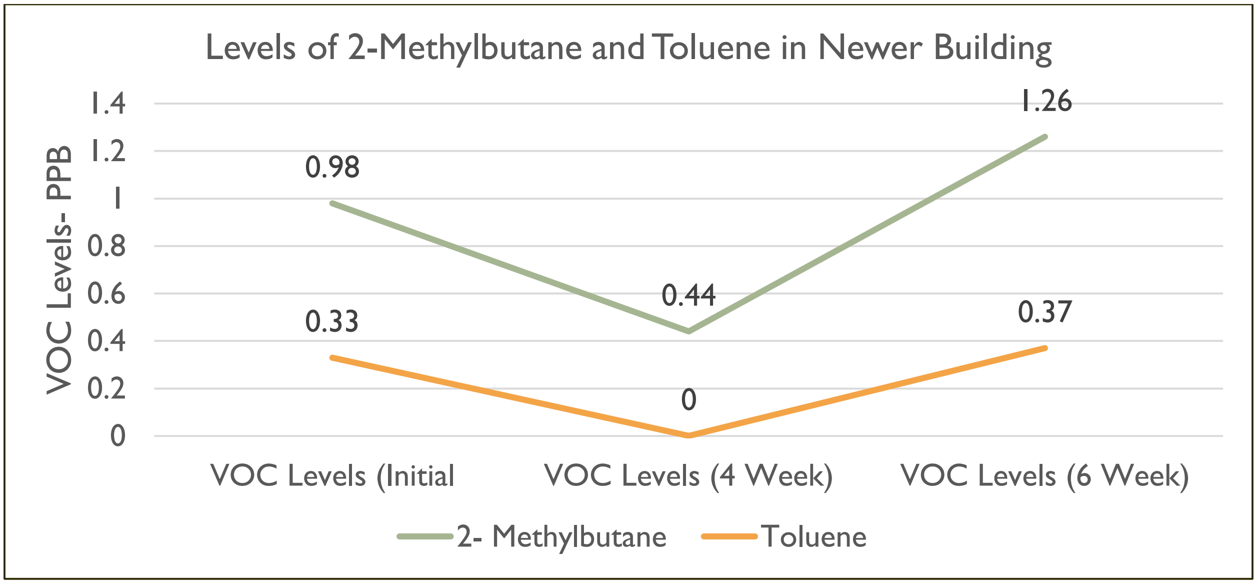
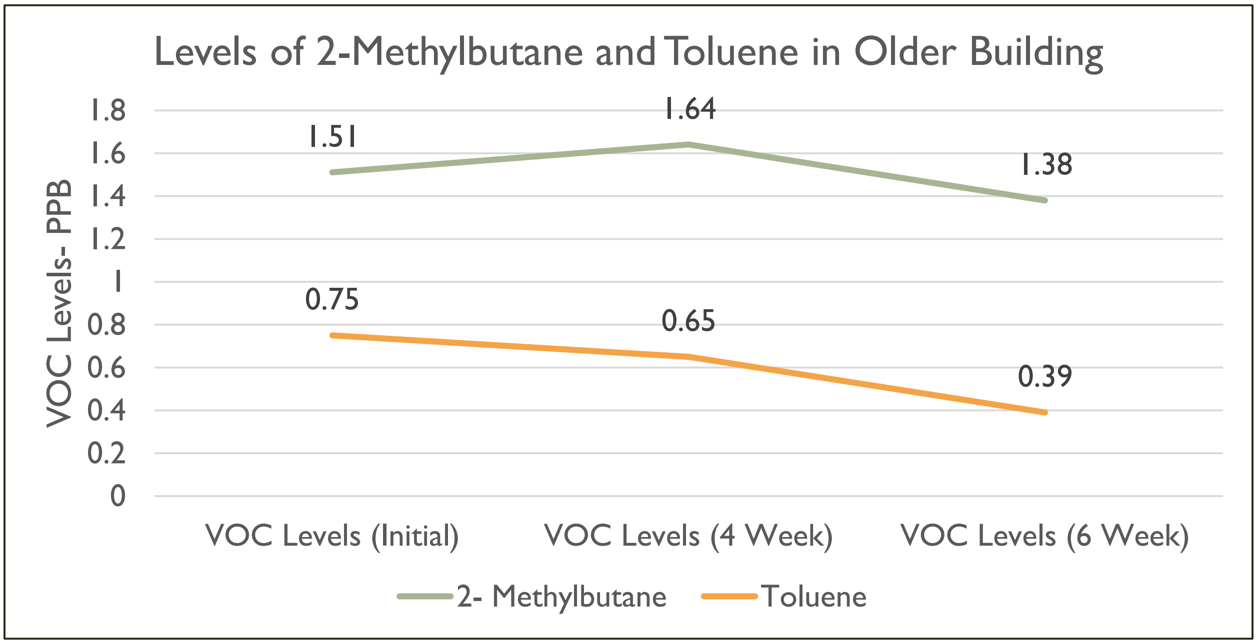


Figure 2- Level of 2-mehtylbutane and toluene levels before and after adding plants (week 4 and week 6) in the older building



Positive and Negative Results

Positive results (decrease in VOC levels) and negative results (increase in VOC levels) include ‘post-plant’ four week and six week levels.

Positive results. In the newer building, four weeks after the addition of plants, 2-methylbutane decreased an average of 0.54 ppb and toluene decreased an average of 0.33 ppb. In the older building, four weeks after the addition of plants, toluene decreased an average of 0.10 ppb. In the newer building, six weeks after the addition of plants, neither VOC level decreased. In the older building, six weeks after the addition of plants, 2-methylbutane decreased an average of 0.26 ppb and toluene decreased an average of 0.26 ppb. Decreases were observed at the four week levels in three of the four measurements and the six week levels in two of the four measurements. Overall, decreased levels of VOCs were detected in five out of the eight ‘post-plant’ measurements.

Negative results. In the newer building, four weeks after the addition of plants, neither 2-methylbutane or toluene levels increased. In the older building, four weeks after the addition of plants, 2-methylbutane levels increased an average of 0.13 ppb. In the newer building, six weeks after the addition of plants, 2-methylbutane levels increased an average of 0.82 ppb and toluene levels increased an average of 0.37 ppb. In the older building, six weeks after the addition of plants, neither VOC level increased. Increases were observed at the four week levels in one of the four measurements and the six week levels in two of the four measurements. Overall, increased levels of VOCs were detected in three out of the eight ‘post-plant’ measurements.

Discussion

Major Patterns Observed

There appears to be an association between decreases in the level of 2-methylbutane and toluene and the addition of plants to the offices. However, this was a pilot study and there were not enough samples in this study to run statistical analysis. Therefore, future studies need to be conducted with more samples.

Predicted Causes of Patterns

Decreased levels (positive results) in this study appear to be related to plants removing VOCs from the offices. This is in agreement with others (Aydogen & Montoya, 2011; Sriprapat & Thiravetyan, 2013; Wolverton, 2009). Since 2-methylbutane and toluene levels were not consistently lower than the initial measurement it is difficult to precisely conclude that plants decreased those levels. However, other studies found that increased levels (negative results) appear to be related to increased temperatures and sun exposure ‘secondary emissions’ (Qian, Zhang, Little, & Wang, 2007; Wolkoff & Nielsen, 2001; Kagi, Fujii, Tamura, & Namiki, 2009). Close proximity of the older building to a construction site may have affected levels. However, both positive and negative results are in agreement with previous research studies (Aydogen & Montoya, 2011; Sriprapat & Thiravetyan, 2013; Wolverton, 2009).

Possible limitations. Some limitation of this study are: 1) not measuring the temperature and humidity which are associated with the level of VOCs that emit from building materials by means of ‘secondary emissions’, 2) having construction activities close to the offices that were selected for this study, 3) not be able to control sunlight exposure considering that all four offices had large windows.

Significance of results

There were, in fact, positive results; meaning that plants are effective at reducing exposure to indoor VOCs. Negative results may be avoided in future studies by selecting more offices and eliminating limitations.

Conclusion

Access to conventional ways of reducing indoor VOCs, such as air purifiers, air filters and ventilation, may not be feasible. A growing body of research, including this study, seeks alternative methods, such as phytoremediation (i.e. addition of plants), to help purify indoor air, thus improving overall health. Educating the public of these cost effective methods in improving indoor air quality is one of the many ways nurses can help improve the overall health of the population. Just as important as adding plants, reducing direct sun exposure and keeping consistent humidity levels and temperature greatly reduce secondary emission of VOCs.

Healthcare in relation to this study

Improving overall health by decreasing chronic exposure to indoor air pollution can optimize an individual's quality of life. Steps taken towards preventative health measures, no matter how small, will positively impact the body overtime. Based on the large amount of time individuals spend indoors, the impact of reducing VOCs indoors could be significant for improving long term health and avoiding the adverse effects of VOCs.

Recommendations

Recommendations for future research includes: monitor/regulate environmental temperature and sunlight exposure in the room, monitor humidity and sun exposure. Other suggestions include having a control group in a similar setting to be tested every time an experiment group is tested. Increases and decreases of VOCs may be observed in the same pattern for both control and experiment groups, and those levels can be compared. Increased levels observed with plants could still be much less than increased levels observed without plants.

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Appendix A

List VOCs measured by monitor

Acetone
Acetonitrile
Acrylonitrile
Ally Chloride
Alpha-Pinene
1-Butyl Alcohol
2- butanone (MEK)
2-Butyl Alcohol
Benzene
Benzene, 1-Chloro-4(Trifluoromethyl)
Benzyl Alcohol
Benzyl Chloride
Butane
1,3-Butadiene
Butyl Acetate
Butyl Cellosolve
Butyl Ether
Carbon Tetrachloride
Cellosolve
Chlorobenzene
Chloroform
Cyclohexane
Cyclohexanol
Cyclohexanone
Cyclohexene
Diacetone Alcohol
1,2 Dichlorobenzene
1,4-Dichlorobenzene
1,2 Dichloroethane
1,2 Dichloromethane
Decane
Diethylene Glycol Ethyl Ether
Diethylene Glycol Monobutyl Ether
Diethylene Glycol Monobutyl Ether Acetate
Dimethyl Fumarate
Dioxane
Dipropyle Glycol Methyl Ether
Dodecane
d-Limonene
Ethyl Acetate
Ethyl Acrylate
Ethyl Alcohol
Ethyl Benzene (Ethyl Benzol)
Ethyl Ether
Ethyl Methacrylate
1-Hexanol
1-Hexyne
2-Heptanone
Heptane
Hexane
Hexone (MIBK)
Isobutyl Acetate
Isobutane
Isooctane
Isopropyl Alcohol
1-Methyoxy-2propanol
2-Mercaptoethanol
5-Methyl-2-Hexanone (MIAK)
2-Methylbutane
MEK Oxime
Methyl Acetate
Methyl Acrylate
Methylbromide
Methyl Chloroform
Methyl Methacrylate
Methyl Styrene
Methylene Chloride
Methyl-t-butyl Ether
Nonane
n-Propyl Acetate
n-Propyl Bromide
Octane
2-Pentanone
2-Proopoxy Acetate
1-Pentanol
Pentane
Pentyl Acetate
1-Methyl-2-Pyrrolidone

2-Ethyl-1-Hexanol
2-Ethylhexyl Estee Acetic Acid
4-Ethyl Toluene
Epichlorohydrin
Styrene
Tetrahydrofuran
Toluene (Methylbenzene)
Triacetin
1,1,2 Trichloroethylene
1,1,2,2 Tetrachloroethane
1,2,4 Trichlorobenzene
3-Methylhexane
2-Methylhexane
2,5-Dimethylhexane

2-Methylpentane
3-Methylpentane
2,3-Dimethylpentane
3,3-Dimethylpentane

Methylcyclohexane
Methylcyclopentane

1,2-Dimethylcyclopentane
1,2-Dimethylcyclohexane

2-Methylheptane

Dimethoxymethane
2-Methyl-1-Propanol
2-Methyl-2-Propane
Methyl t-Butyl Ether
1-Butanethiol
2-Butanethiol
Butyl Disulfide
Carbonyl Sulfide
Chloromethane

Eucalyptol
Methyleugenol
Bourgeonal
Perchloroethylene
Propyl Benzene
Propylene Glycol Methyl Ether Acetate
Propylene Oxide
Pyridine
1,1,1-Trichloroethane
Trichloroethylene
1,2,4-Trimethylbenzene
Undecane
Vinyl Acetate
Vinyl Chloride
Vinylcyclohexane
Xylene
Estragole
Bourgenol
Anethole
Camphene
Methylparacresol
Furfuryl Alcohol
Estragole
2-Methyl-1-Butyl Acetate
Diacetyl
2-Hexenal
Acetylpropionyl
Isobutyl Isobutyrate
Urethane
Iosprene
Camphor
1,2-Dichloroethylene
Dimethyl Sulfide
5-Methyl Sulfide
o-Cymene
m-cymene
t-Butyl Acetate

Appendix B

Information about Advanced Chemical Sensors, Inc. Monitors Used in This Study.

There are no moving parts. The device weighs less than 1 ounce (28 grams). Air diffuses through a micro-porous membrane, and collects on special prepared adsorbents inside the monitoring badge. The ACS laboratory analyzes the chemicals collected, and reports the average concentration while the device was exposed (Advanced Chemical Sensors, 2014).

ACS Full Scan Organic Vapor Monitor (Formaldehyde analysis is not included). Catalog No. OV-00 (Advanced Chemical Sensors, 2014).

ACS Formaldehyde Vapor Monitor. Catalog No. F-50 (Advanced Chemical Sensors, 2014).

Appendix C

Level of VOCs Measured in the Newer Building

Room 1	**Initial Testing**	**4 Week Post Plant**	**6 Week Post Plant**
Butane	1.00 ppb	1.20 ppb	1.60 ppb
Ethyl Alchohol	2.24 ppb	1.50 ppb	3.35 ppb
Acetone	1.60 ppb	1.22 ppb	2.41 ppb
Toluene	0.33 ppb		0.37 ppb
2-Methylbutane	0.85 ppb		1.16 ppb
Formaldehyde	0.003 ppm	0.007 ppm	0.002 ppm

Appendix D

Level of VOCs Measured in the Newer Building

Room 2	**Initial Testing**	**4 Week Post Plant**	**6 Week Post Plant**
Isobutane	0.62 ppb	0.60 ppb	0.82 ppb
Butane	1.11 ppb	1.18 ppb	1.66 ppb
Ethyl Alcohol	2.72 ppb	1.41 ppb	3.06 ppb
Acetone	3.05 ppb	1.79 ppb	2.81 ppb
2-Methybutane	1.10 ppb	0.88 ppb	1.36 ppb
Formaldehyde	0.003 ppm	0.007 ppm	0.003 ppm

Appendix E

Level of VOCs Measured in the Older Building

Room 3	**Initial Testing**	**4 Week Post Plant**	**6 Week Post Plant**
Isobutane	0.98 ppb	0.78 ppb	0.82 ppb
Butane	1.87 ppb	2.77 ppb	2.53 ppb
Ethyl Alcohol	5.39 ppb	4.37 ppb	5.56 ppb
Acetone	2.37 ppb	2.43 ppb	1.98 ppb
2-Methylbutane	1.60 ppb	1.76 ppb	1.50 ppb
Pentane	1.76 ppb	0.72 ppb	0.65 ppb
Methyl Ethyl Ketone	0.61 ppb	0.74 ppb	0.55 ppb
Ethyl Acetate	1.05 ppb		
Tolouene	1.49 ppb	0.44 ppb	0.45 ppb
Formaldehyde	0.005 ppm	0.005 ppm	0.003 ppm

Appendix F

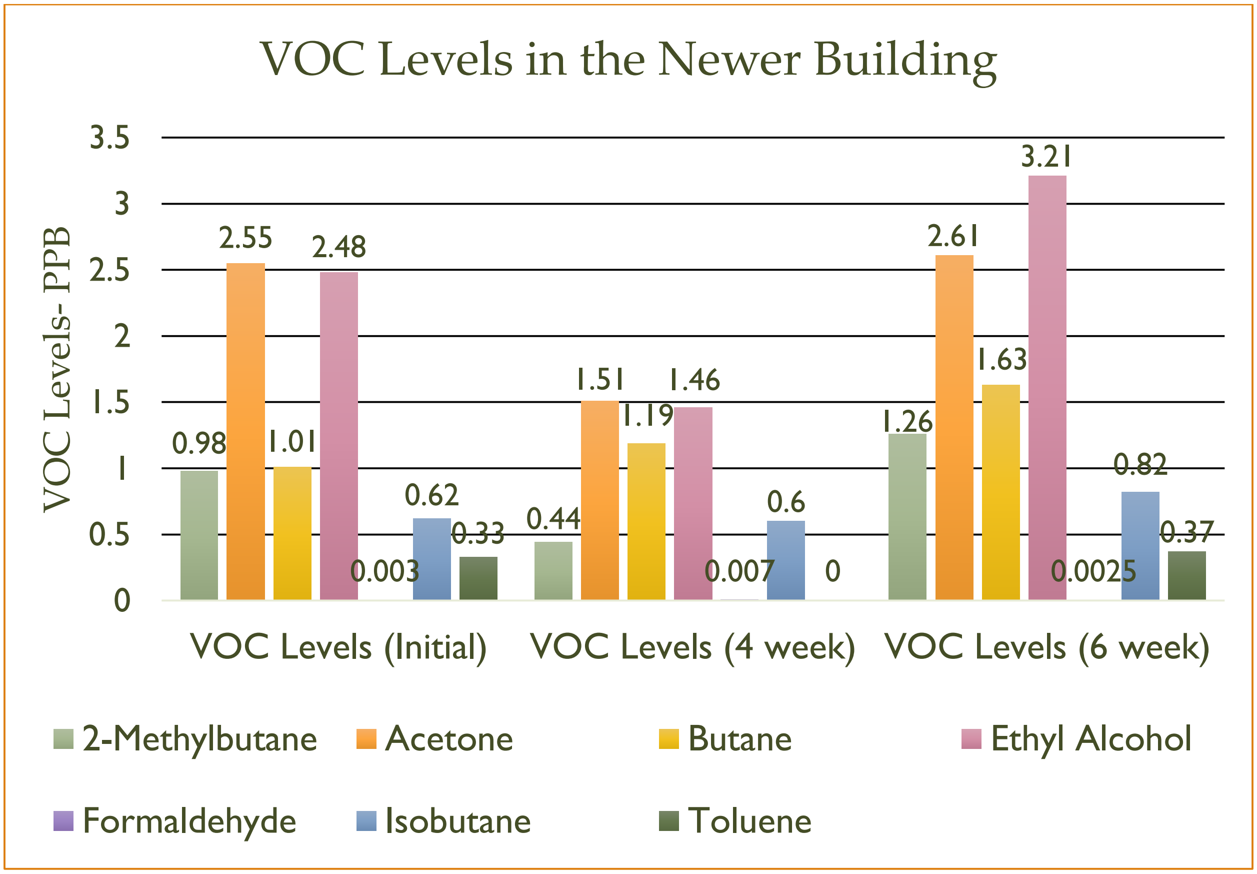
Level of VOCs Measured in the Older Building

Room 4	**Initial Testing**	**4 Week Post Plant**	**6 Week Post Plant**
Isobutane	0.68 ppb	0.94 ppb	
Butane	1.51 ppb	9.90 ppb	1.18 ppb
Ethyl Alcohol	4.82 ppb	6.54 ppb	2.32 ppb
Acetone	1.89 ppb	6.63 ppb	1.97 ppb
2-Methylbutane	1.42 ppb	1.76 ppb	1.26 ppb
Methyl Ethyl Ketone	0.63 ppb	0.87 ppb	0.72 ppb
Toluene		0.85 ppb	0.33 ppb
Formaldehyde	0.007 ppm		0.003 ppm

Appendix G

Bar Graph

This graph shows the average level of identical VOCs found in office one and two. Excluded are VOCs not present in both of the offices.



Appendix H

Bar Graph

This graph shows the average level of identical VOCs found in office three and four. Excluded are VOCs not present in both of the offices.