Impact of Plant Life on Formaldehyde Levels in an Existing Office Setting In the UAE

تأثير حياة النبات على مستويات الفورمالديهايد في مكتب من المكاتب الموجودة في الإمارات العربية المتحدة

By

Isra Ibrahim AbuZayed

Student ID: 100057

Project submitted in partial fulfilment of the requirements for the degree of MSc Sustainable Design of the Built Environment

Faculty of Engineering & Information Technology

Module Coordinator

Professor Bassam Abu-Hijleh

April-2015

APPENDIX A

DISSERTATION/PROJECT RELEASE FORM

Student Name	Student ID	Programme	Date

Dissertation/Project Report Title

I warrant that the content of this Dissertation/Project Report is the direct result of my own work and that any use made in it of published or unpublished copyright material falls within the limits permitted by international copyright conventions.

I understand that one copy of my dissertation/project report will be deposited in the University Library for permanent retention.

I hereby agree that the material mentioned above for which I am author and copyright holder may be copied and distributed by The British University in Dubai for the purposes of research, private study or education and that The British University in Dubai may recover from purchasers the costs incurred in such copying and distribution, where appropriate.

I understand that The British University in Dubai may make that copy available in digital format if appropriate.

I understand that I may apply to the University to retain the right to withhold or to restrict access to my dissertation/project report for a period which shall not normally exceed four calendar years from the congregation at which the degree is conferred, the length of the period to be specified in the application, together with the precise reasons for making that application.

Signature

Executive Summary

The toxin formaldehyde has been associated with muscle weakness, itchy eyes/ skin and is considered a carcinogen. Plant life has been long associated with cleaning air and improving IAQ levels. Therefore this study will look at the impacts of plant life (Corn Cane plant) on formaldehyde levels within an existing office set in the United Arab Emirates.

3 spaces within the office were selected and labeled as space A, space B and space C. The plants were included within these spaces, each with a different space/plant ratio. The results showed that the plants where able to reduce the most amount of formaldehyde levels when introduced at a highest plant/space ratio of 3.75m2/plant (Space B). When equated there was a total drop of 4% in formaldehyde levels within space B.

The occupants of the space were also surveyed to determine the effect of the reduced formaldehyde levels on their perceived health and efficiency. It was concluded that although the survey results exhibited great improvement within the office, there was no direct relationship between their improvement and reduction of formaldehyde levels.

Recommendations for future research:

1) Conduct the research in a more controlled environment for optimized results.
2) Increase to plant / space ratio in order to achieve greater results.

Keywords: Indoor Air Quality, Formaldehyde, toxins, United Arab Emirates, plant life

التنفيذي الملخص

ارتبطت مادة الفورمالديهايد السامة مع ضعف العضلات, حكة العينين و البشرة ، و تعتبر مادة مسرطنه.

لطالما ارتبطت الحياة النباتية مع تنقيه الهواء و تحسين مستويات ال IAQ .

ولذلك فإن هذه الدراسة إلقاء نظرة على آثار الحياة النباتية (نبات قصب الذرة) علس مستويات الفورمالديهايد في نطاق مكتب في الامارات العربية المتحده .

تم اختيار 3 مساحات داخل المكتب و تم تسميتهم بمساحة A, B و C.

تم ادراج النباتات ضمن هذه المساحات ، ولكل منها نسبة مساحة نباتية المختلفة.

و اظهرت النتائج ان النباتات تمكنت من تقليص اكبر قدو من مستويات الفورمالديهايد في المساحه B على نسبة المساحة النباتية 3.75 متر مربع للنبتة الواحدة.

حسابيا هذا يدل على ان هناك انخفاض إجمالي قدره 4٪ في مستويات الفورمالديهايد ضمن مساحة B.

تم ايضا جمع و مسح العاملين في المساحات لتحديد تأثير خفض مستويات الفورمالديهايد على ما يعتقد من مستويات الكفاءة و الصحة.

تم التوصل إلى أنه على الرغم من أن نتائج المسح أظهرت تحسنا كبيرا داخل المكتب ، لم يكن هناك علاقة مباشرة بين تحسينها والحد من مستويات الفورمالديهايد .

توصيات للبحوث المستقبلية :

إجراء البحوث في بيئة خاضعة اكثر للرقابة لنتائج أمثل.

زيادة نسبة مساحة النباتيه من أجل تحقيق نتائج أفضل .

كلمات البحث: جودة الهواء الداخلي ، الفورمالديهايد ، والسموم ، الإمارات العربية المتحدة ، الحياة النباتية

Acknowledgements

To the British University in Dubai and Prof. Bassam Abu-Hijleh for being the perfect vehicle in which my educational journey was guided.

My family,

To my father for being my inspiration. For his undivided belief in everything that I am and everything that I will be. For always pushing me to be the best version of myself.

For my mother's constant and undying support. With you by my side, I can never fail. From you, I have learnt how to be a strong, honest and proud woman.

Elesar for the guidance.
Fajer for the escape.
Mojo for the company.

Zaid, for his undying support in any and every journey I choose. Always encouraging me to exceed and excel.
Tamara, I started this journey before you, and now I am completing it for you, so that one day you can be proud of your mother's accomplishments.

Thank you

Table of Contents

List of Tables

1 Introduction

The United Arab Emirates is a country that has emerged from the sands of the gulf desert in a mere 43 years. What is now a world renowned country with metropolitan cities has evolved greatly over the last 4 decades. This success was reached through innovative design of buildings which were executed in a timely fashion.

But during the years in which the UAE was developing their urban landscape, a concern began to develop in the construction and design industry over the quality of the environments of such indoor spaces. This concern entailed both the quality of the indoor air environments, as well as the ways in which people interacted with these spaces.

In the early 1970s structures were built with the aim of maximizing internal thermal comfort, increasing efficiency and cutting costs. Architects and engineers alike worked towards insulating these spaces in order to ensure that the occupants could be comfortable. This in turn led to occupants spending the majority of their time indoors; be it, at home, the work place or leisure time. The comfort levels that were achieved encouraged people to begin depending entirely on interior spaces; which began a dependence on HVAC systems to clean and filter indoor air.

Furthermore to the sealed interiors, was the addition of toxins to the spaces. Toxins were (and still continue to be) emitted within interior spaces through insulation, paints and finishes, furniture and cleaning products. This toxic build up within the space became a source of illness and put people at risk of contracting diverse diseases. Toxins such as VOCs, which are chemicals containing carbon and hydrogen, have been proven to have adverse health effects if founds within a space.

One common type of VOCs is Formaldehyde (HCHO). Formaldehyde has been associated with muscle weakness, itchy eyes/skin and is considered a carcinogen. The toxin poses a risk to occupants of a space when found at high concentrations.

Indoor air quality has now become a serious concern. The risks at which inhabitants are facing if indoor air quality is of a poor quality are severe. As the United Arab Emirates continues ti progress towards an innovative future it is vital to consider the wellbeing of occupants through healthy indoor air quality.

Past research has shown a connection between the presence of plant life within a space and their ability to reduce and absorb such toxins. One of the most commonly known methods of plants aiding the reduction of toxins is the carbon dioxide and oxygen exchange. Recent research has connected the presence of plant life within our interiors as a means of connecting back to nature. Plant life has the ability to help stabilize certain toxins within a space. The presence of plant life can also be directly linked to the reduced amount of airborne moulds and bacteria within a space. Further research has associated plant life with the ability to reduce VOCs from interior spaces (IEQ indoor plants n.d.).

In order to determine the depth at which plant life may impact toxins within the interior more research is needed. Through this research, a study will be conducted in order to determine the ability of plant life to impact the formaldehyde levels of an office interior set in the United Arab Emirates.

This research will begin with a look at the present literature available on the topic of formaldehyde and its determining factors and how plants impact the interior environments. Through the literature review of plant life, a single species of plants will be selected in order to proceed with. With this a knowledge gap will be discussed in order to bridge the connection of how this research is needed. Furthermore, the aims and objectives of the study will be discussed and followed through with the methodology. Within the methodology the research steps and tools will be discussed in order to have a full understanding of the process and what it entails. Then the results will be discussed thoroughly, which will lead to the final conclusion and recommendations for future research.

2 Literature Review

In order to further identify the need for an indoor air quality solution within the UAE a look at recent research is needed. The research will be divided into three main sections in order to develop the needed data.

1. Formaldehyde sources and factors
2. Guidelines : Formaldehyde levels
3. Impacts of plant life on IAQ

2.1 Formaldehyde Sources and Factors

Formaldehyde is a colourless gas at room temperature and can be found within our atmosphere. It is emitted though natural and pollutant sources. It can be found naturally within the environment through forest fired and volcanoes. Whereas, through pollution, it is introduces into the atmosphere through power plants and incinerations (WHO 2010).

According to the WHO (2010) formaldehyde within indoors is a toxin which needs to be monitored. Large concentrations of this toxin found within a space and exposed through inhalation can have adverse health effects to the occupants. Formaldehyde can be introduced to building interiors through material emissions and combustible activities such as smoking, cooking or lighting candles. In addition it is also used as a resin and preservatives in many manufacturing processes.

Also mentioned by the WHO is that some of the factors which determine the rate at which formaldehyde is emitted into the environment are the furniture age and density. New furniture emits toxins at a higher rate resulting in an increase in formaldehyde levels, whereas old or used furniture has allowed the emissions to fade over the years (2010).

As noted in Table 1 – Formaldehyde Emissions, medium density fiberboard contains the highest emissions of formaldehyde levels. This showing that the type of furniture found within a space plays a key role in the indoor air quality (Godish,1989).

Table 11 - Formaldehyde Emissions

	Range of Formaldehyde - Emission Rats - µg/m²/day
Medium-density fiberboard	17,600-55,000
Hardwood, Plywood paneling	1,500-34,00
Urea-formaldehyde foam insulation	1,200 – 19,200
Fiberglass products	400-470
Carpeting	NP*-65

According to the EPA, everyone is exposed to some levels of formaldehyde that are off-gasses from products. Products which are produces through composite woods have the highest rate of formaldehyde emissions. This is due to the high amount of formaldehyde resin added to the wood. In 2010 President Obama signed a legislation which aims to set and police a standard on the amount of emitted formaldehyde from these products (2015).

Raw et al, conducted a large scale study which surveyed 876 homes located in the UK, in order to determine the factors which impact the increase of formaldehyde levels on a space. It was concluded that the age of the building was an important aspect of determining the formaldehyde concentrations. More specifically was the age of the building walls and floor coverings (2004).

Another important factor which affects the levels of formaldehyde is the temperature and humidity. According to the below Table 2 (Effect of Environmental Factors on Formaldehyde) the decrease of temperature has a direct impact on the concentrations of formaldehyde. The same applies for the relative humidity. As the percentage of relative humidity is decreased so do the formaldehyde concentrations. This correlation was first noted through a study published by Godish in 1989, in a book titled ‘Indoor Air Pollution Control.’

Table 12 - Effects of environmental Factors on Formaldehyde

Temperature – Celsius	Relative Humidity %	Formaldehyde Concentrations -Ppm	% of Maximum Value
30	70	0.36	100
25	70	0.29	81
30	50	0.28	78
30	30	0.23	64
25	50	0.17	47
25	30	0.14	39
20	70	0.12	33
20	50	0.09	25
20	30	0.07	19

2.2 Indoor Air Pollutants in the UAE

A recent wide scale research was conduction in the United Arab Emirates in order to determine the indoor air pollutants and their health effects on residence. The research titled 'Indoor Air Pollutants and Heath in the United Arab Emirates', was looking to fill the gap of the deficient amount of information found on the indoor air quality of the UAE. As stated in the reports, 'Little is known about indoor air health risks in the Middle East, especially in countries undergoing rapid economic development'(2012). Yeatts et al., looked at a total of 628 households in the emirate of Abu Dhabi. Before conducting the indoor air quality tests, the researchers made sure to note any additional environmental factors that the space was exposed to on a regular basis. Some of these factors where, tobacco smoke, candle incense and gas stoves. These factors where noted as they have a great impact on the indoor air quality as well as the health of the occupants (2012).

As a result of the testing, it was concluded that there was a direct connection between high levels of toxins. If toxins such as SO2 (Sulfur Dioxide), NO2 (Nitrogen Dioxide) and H2S (Hydrogen sulphide) where found within a space, the occupants of that space were noted to be twice as likely to be diagnosed with asthma. A fourth toxin was also identified as being associated with neurologic symptoms such as muscle weakness. HCHO or Formaldehyde along with SO2, NO2, and H2S were the four prominent toxins identified in the indoor environments of over 600 residential spaces in Abu Dhabi, UAE. Formaldehyde was recorded at a rate of 0.137ppm (2012).

2.3 Guidelines

According to the ASHRAE Standard on Ventilation for Acceptable Indoor Air Quality (2007), there is no set standard to be adhered to for formaldehyde levels, but however there is a noted recommendation that is made. The target level or formaldehyde within a space should be 0.05ppm. It is also noted that the maximum limit of formaldehyde within a space should not exceed 0.1ppm. With that, it is also added that due to the undeveloped research on the adverse health effects of formaldehyde, it is advisable to maintain the toxin at the lowest level possible.

Noted below in table 3 is a list of guidelines (2011) that have been set by various organizations. The Illinoi Department of Public Health (IDPH) has set the formaldehyde levels at a maximum of 0.1ppm in an office setting. Which, relating to previous research, is the maximum point at which people can be within an office setting without beginning to feel adverse health effects.

Table 13 - Summary of Guidelines

PARAMETER	IDPH	ASHRAE	OSHA PEL *	ACGIH TLV **
Humidity	20% - 60%	30% - 60%	N/A	N/A
Temperature	68° - 75° (winter)	68° - 75° (winter)	N/A	N/A
	73° – 79° (summer)	73° - 79° (summer)		
Carbon Dioxide	1,000 ppm (<800 ppm preferred)	1,000 ppm	5,000 ppm	5,000 ppm
Carbon Monoxide	9 ppm	9 ppm	50 ppm	25 ppm
Hydrogen Sulfide	0.01 ppm	N/A	20 ppm	10 ppm
Ozone	0.08 ppm	N/A	0.1 ppm	0.05 ppm
Particulates	0.15 mg/m^3 (PM 10) (150 µg/m^3) 24-hr 0.065 mg/m^3 (PM 2.5) (65 µg/m^3) 24-hr	N/A	15 mg/m^3 (total) 5 mg/m^3 (resp.)	10 mg/m^3 (total) 3 mg/m^3 (resp.)
Formaldehyde	0.1 ppm (office) 0.03 ppm (home)	N/A	0.75 ppm	0.3 ppm

This then leads the questions as to the accuracy and dependability of the standards set by the

OSHA-PEL, Occupational Safety and Health Administration Permissible Exposure Limit and the ACGIH TLV, American Conference of Governmental Industrial Hygienists Threshold Limit Value.

Within the United Arab Emirates, and more specifically Dubai the Dubai government has set Green Building Regulations & Specifications in 2011. The regulations shown in table 4, clearly state that the maximum amount of acceptable formaldehyde levels in existing building in Dubai is to be less than 0.08ppm, as tested through an 8 hours continuous monitoring (2011).

Table 14 - Indoor Air Quality Compliance: Existing Buildings

Sampling Schedule	Type of Samples	Maximum Acceptable	Sampling Duration
Initial test completed by 31 December 2011. Further testing within 5 years of last compliant test.	Formaldehyde	< 0.08 ppm	8- hour continuous monitoring (8 hour time-weighted average [TWA])
	Total Volatile Organic Compound (TVOC)	< 300 micrograms/ m^3	
	Respirable Dust (<10 microns)	< 150 micrograms/ m^3	
	Ozone	0.06 ppm (120 micrograms/ m^3)	
	Carbon Dioxide	800 ppm (1440 microgram/ m^3)	
	Carbon Monoxide	9 ppm (10 micrograms/ m^3)	
	Bacteria	500 CFU/ m^3 (Algar plate)	
	Fungi	500 CFU/ m^3 (Algar plate)	

During this research process, the Dubai government guidelines for formaldehyde levels will be utilized as a measure of comparison.

2.4 Ability of plant life to reduce toxins

In a research conducted in 2009 by the School of the Built Environment, Liverpool John Moores University, a study was conducted about the benefits of introducing plant life into the corporate world. Through extensive literature review, it was concluded that plant has two main benefits when added to an office interior. The initial benefits are of reducing the amount of toxins or pollutants from the space. But the second finding, which proved to be the most beneficial was the in-office moral (2009). Employees had a more positive outlook and an improved sense of wellbeing. As a result of this, there was a sense of greater productivity amongst the staff. Although the research does identify that some of the positive effects on the staff is psychological. But be it physiological or not, the addition of plant life to the space played a key role in benefiting the inhabitants.

Researchers from around the worlds gathered at the 8th International Indoor Air Conference. The majority of the findings that researchers were discussing related to the deteriorating levels of indoor air quality. But two researchers at the conference presented findings related to the use of plant life in order to help improve the IAQ.

Wood (2006) looked at the ability of three commonly used house plants to reduce the levels of certain VOCs. His research showed that the plant's ability to absorb toxins from the air increased as the amount of toxins increased. Toxins were presented to the plants from a variety of sources that people are exposed to on a daily basis such as, tobacco smoke, paints and photocopy machines. The research was carried out over a period of 30 days and the plant's growth was not affected by the consumption of toxins around it (Wood, 2006).

Professor Tore Fjeld of the Agricultural University of Norway looked at common conditions which occupants of work places commonly feel due to poor IAQ levels. Through the use of everyday house plants, she looked at the possible benefits to the employee's heath. The plants where tested over 2 spaces, the first being an office setting and the second being an x-ray department within a hospital. After the addition of the plants there was an improvement in the health of both groups. The occupants of the office space showed a 23% reduction of symptoms such as headaches and tired muscles, whereas the x-ray department noted an improvement of 25%. Professor Fjeld recognised that the positive results were due to the improved indoor air

quality as well as the increase humidity caused by the plants. She also added that the psychological factors of having plant life at your place of work played a role as well (Fjeld, 2006). Occupants enjoyed being close to plant life and liked to feel connected with nature and for that reason they experience lower stress levels around plant life.

Ovabu et al. (2003) discusses the ability of plants life to remove odours from within a space. Research showed that the removal of the ammonia odour from the space was most effective. It also linked the ability of a plant to reduce odours with the molecular weight of the odour. This conclusion stating that the plant is able to absorb more odours at a lower molecular weight.

Orwell et al. conducted a lab experiment to determine the ability of a plant and the plant's root (microorganisms) to reduce TVOC. The laboratory conducted study looked several houseplants which were exposed to a variety of levels of TVOC (ranging from 0.2 to 100ppm). It was concluded that plants and the microorganisms in the roots were able to self-regulate in order to absorb a larger quantity of TVOC as their presence within the space increased (2006).

In another research conducted in 2004, seven potted plants where tested for their ability to remove the toxin benzene from an enclosed chamber conducted through a laboratory research. It was determined that the plants were able to remove high doses of benzene from within the chamber within 24 hours (Orwell, 2004).

Wood et al. (2002) looked at 3 common house plants and their ability to reduce common airborne VOCs. It was concluded that the plant life has the capability to act as a sustainable bio filtration system within a space. The plant's air cleaning capability along with the psychological and aesthetic benefits make it an ideal solution to incorporate within a home or office.

2.5 Plants and Formaldehyde

This part of the literature review will look at past research which has determined certain species of plants that are able to absorb and minimize the existence of formaldehyde levels from within a space. This will intern help to determine the species of plant which it best suited to reduce e the

formaldehyde levels within office interiors in the UAE.

Giese (1994) looked at the ability for plant life to reduce the formaldehyde toxin. The research was conducted in a laboratory setting and examined at a chemical level. It was determine that the formaldehyde toxin, when absorbed by a common house plant such as the spider plant, undergoes an oxidization process which leads to the detoxification of the formaldehyde toxin

Kim et al. (2008) conducted a lad study to identify the ability of the 'Fatsia Japanica' plant to reduce formaldehyde levels within a laboratory setting. It was concluded that the plant was able to reduce the formaldehyde levels at a greater rate during the night hours. This was due to the microorganisms which are found within a plant's roots.

In the summer of 1993, 2 researchers for the Wolverton Environmental Services department conducted a laboratory research that was able to identify the ability of different plant species to reduce certain toxins from an interior environment. Through the laboratory method they were able to isolate and test the plants and the toxins in a completely sealed environment. Their results were very beneficial to the IAQ researchers, and it is still referenced and shared. They were able to look at the ability of the plant and the soil together, as one entity in order to further understand how the toxins are reduces. It concluded that the Lady Palm and the Boston Fern were the two plants with the highest ability to reduce the carcinogen toxins, formaldehyde (HCHO) from interior (1993). It was also noted that as the plants were exposed to the toxin for a longer amount of time, they were able to adapt and absorb a greater amount of the formaldehyde. This then allowed the conclusion that certain microorganisms found within the plant's soil are adapting their ability to lower the amounts of the toxin. (1993).

According to Sustainablebabysteps.com there are three main toxins which are of concern to residential spaces. One of the three toxins is formaldehyde. However there are plants that have been previously identified which have the capability to reduce formaldehyde levels within interiors (Sustainable Baby Steps n. d)

- Aloe Vera

    - The Aloe Vera plants have the ability to reduce formaldehyde levels. It needs minimal water but requires sunlight to grow. It is a plant that is native to the region but unfortunately can cause irritation as its pointy and prickly ends might be harmful to some
- Baby Rubber Plant
    - This is a common house plant that can purify air and reduce formaldehyde levels. The plant requires constant sunlight and minimal water. However it can cause irritation to some as it has allergic properties
- Boston Fern
    - Humidifies the air and relieves it of formaldehyde levels. The plant requires bright light and a constantly damp soil. The plant can be comfortably incorporated into an environment but due to its high maintenance requirements it is not ideal for an office setting
- Chinese Evergreen
    - This plant emits oxygen in exchange for purifying the air and removing chemicals such as formaldehyde. The plant does not require a large amount of sunlight or water. It is however considered poisonous and is not ideal for an office setting
- Corn Cane
    - This plant is known for the reduction of formaldehyde levels. It is commonly found as a house plant. It also can survive easily with a low amount of light and a low volume of water.

3 Knowledge Gap

In the United Arab Emirates people spend more than 90% of their time indoors. While indoors, there is a complete reliance on HVAC systems. These systems, which are means to alleviate the environment of toxins, are particles are not always reliable.

The above conditions along with the lack of research documented on the indoor air quality within the UAE is a great motivational factor . In addition to this, a recent research conducted by Yeatts et al. in (2012) placed emphasis on the heightened levels of formaldehyde found within homes in the UAE.

Office workers in the UAE spend a minimum of 8 hours a day indoors. Within these office spaces, the entire airflow system is conducted by the HVAC system. Employees are left with no choice but to depend on the HVAC to achieve thermal comfort some buildings and institutes going as far as preventing people from opening windows. In addition to this the majority of office furniture is MDF wood (desks and shelving units) which has been shown to emit the highest concentrations of formaldehyde (Godish 1989).

This complete dependence on the HVAC system, along with the previous research which raised concern in relation to formaldehyde, creates a gap of formaldehyde testing in an office setting as well as attempting to find a possible solution.

4 Aim of Study

The aim of the study is to determine the impacts of a selected plant life on the formaldehyde levels within an existing office interior in Dubai.

The first step of the study is to identify an office set within the UAE with relatively high formaldehyde levels. Once this is established then the following aims with be developed

1. Can the selected plant life reduce formaldehyde levels in an office?
2. If so, will reduction of formaldehyde levels have any effect on employee moral / perceived health?

3. Will the presence of plant life have effects on employee moral / perceived health?

5 Methodology

Determining the impacts of plant like on the formaldehyde levels within an existing office in Dubai will be conducted through an experimental procedure using the following steps:

1. Location:
    - The first step to the procedure is to identify a location in which the experiment will be conducted.
2. Interior Space
    - Review the interior spaces that will be selected for the experiment
3. Data Collection
    - Discuss the three steps of data collection needed at each stage of the experiment in order to ensure that independent variable is attaining the correct results
4. Instruments
    - Discuss the three instruments that are utilized in order to aid in the data collection process
5. Plants
    - Selection and discussion of the plant selected for the experimental process
6. Limitations
    - Aspects which limited the experiment from attaining the more efficient results

5.1 Location

The experiment will be conducted in an office space set in Ras Al Khor Industrial Area 1, located in Dubai, UAE. The office is set within a large warehouse. Half of the facility is utilized as storage and the other half is the office area, consisting of 2 floors and a total of 8 work spaces. There are 21 people employed by the company, and 4 of the 21 employees spend the majority of their day out of the office. The remaining 17 employees work primarily at a desk and behind a computer. The company's main service is logistics and clearing.

The warehouse was first built in 1998. It was then fitted out, and furniture in 2003. At the end of 2013, there was a major renovation done within the space, where the interiors were repainted and the addition of partitions was created to accommodate new work areas.

5.2 Interior Spaces

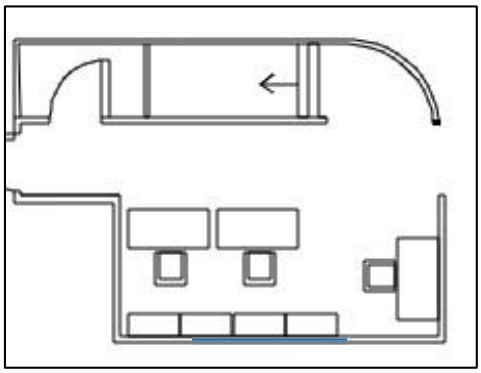


Figure 1- Space A

Three spaces where selected to accommodate the experiment. The first space, Space A, (Figure 1) is located on the bottom floor. There are 3 work stations within the space and 4 storage cabinets. The space is also adjacent to the staircase. There are a total of three people occupying this space. The area contains one window which allows for natural lighting. The window is to remain closed for the entire during of the experiment

The second space selected, is Space B. It is located on the 1st floor. It is the room that contains the three accountants. The room does have one window, but the window is fixed and overlooks another space within the office. The space does not have any natural lighting and therefore does not have the ability to open a window during the one month period. The room is quite dense and contains 3 desks within a tight space.

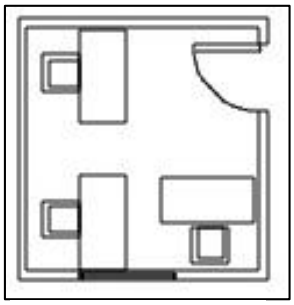


Figure 2- Space B

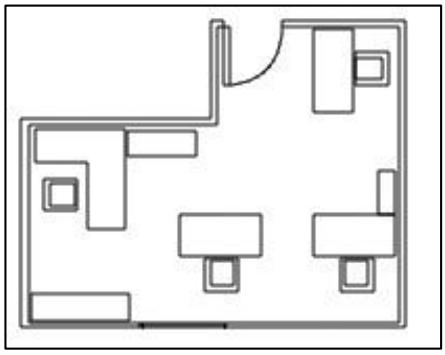


Figure 3- Space C

The third space is also located on the 1st floor. It is the largest of the three spaces and contains 4 workstations with four regular occupants of the space. Referred to as Space C, it also contains a window within the space that allows for natural lighting. As agreed, the window will remain shut for the duration of the experiment.

5.3 Data Collection

There are three methods of data collection required in order to obtain the necessary date from each of the three allocated space (A,B and C).

5.3.1 Method 1: Temperature and Humidity

The first method is the collection and recording of the temperature and humidity within the space. As mentioned by Godish (1989) the presence of the formaldehyde toxin decreased as the temperature and humidity drop. Therefore we need to monitor the temperature and humidity of the formaldehyde levels in order to ensure that the formaldehyde reading attained are not altered due to changed weather conditions. Temperature and humidity of each space are collected through 4 spot checks within each space. It is also important to note that the temperature and humidity of the spaces will be collected between the hours of 2-3pm, both at the initial and secondary data collection steps. It is important to ensure that they are collected at approximately the same time during the day in order to avoid any alterations which might occur due to change in sun exposure leading to changes in temperature or humidity.

5.3.2 Method 2: Formaldehyde

The second method of data collection is through determining the formaldehyde levels. Formaldehyde levels are best estimated within an enclosed space. That is why the selection of the spaces made within the office was geared towards smaller and enclosed spaces. Therefore space A,B, and C are spaces which can help us to obtain those results. Occupants of the space are advised to keep windows shut throughout the experimental period of one month in order to ensure that outdoor contaminants or the addition of natural ventilation do not alter the results. The equipment will be placed on a desk within the center of each room, and left for a total of 9 hours. The first hour of testing is not included within the results as the testing equipment will be in the process of stabilizing. The remaining 8 hours of testing will test continuously over 10 minute intervals, and will record the results in order to allow reading of the results at a later time. This method of data collection is adapted as it is the method advised by the Dubai Government Green Building Regulations and Specifications Handbook (2011).

5.3.3 Method 3: Survey

The third method of data collection is the survey. A survey has been created in order to collect the feedback of the occupants about their perceived health and productivity. Occupants of the

space answered the survey anonymously but are asked to share any health issues which they have recently faced which might alter the survey results.

All of the occupants of the spaces are male and are between the ages of 28-50. As seen in Chart 1, the survey consisted of five symptoms which the occupants were asked to rate on a scale of 'never', 'once in a while' and 'almost daily'.

Date:	Age:	Gender
Amount of hours spent in office/day:	Date you joined the company:	

Please answer the below to the best of your abilities. Within the last 2 weeks have you experienced any of the following:	Never	Once in a while	Almost daily
Headache	◯	◯	◯
Itchy eyes or skin	◯	◯	◯
Sore, dry throat and/or wheezing	◯	◯	◯
Difficulty concentrating	◯	◯	◯
Fatigue	◯	◯	◯

Please note if you have any chronic illness (such as asthma), or habits (such as smoking) which increases the likeliness of experiencing any of the above mentioned:_____

Chart 1 – Employee Survey

5.4 Instruments Used

For the first method of data collection, the Gray Wolf IQ- 610 was utilized in order to record the temperature and relative humidity. As seen in Figure 4, the instrument is hand held and can be easily move from one space to the other to conduct the spot measurements.

The second method utilised the Gray Wolf Formaldehyde (HCHO) Measurement device (Figure 5). The device is to be set up on desktop, within the space, and left uninterrupted for the desired amount of hours.

The third method is the survey circulated to the employees found within the spaces. The survey requested that people share their feedback on 5 different questions relating to perceived heath and productivity. They were asked to rate the frequency at which they experienced these aspects during the last 2 weeks. The reason behind associating the survey with the last 2 weeks is due to the fact that once the survey is conducted a second time, it is to be a review of the last period of time in which the plants had the greatest effect on the inhabitants. This being the last two weeks of the overall month period in which the plants were added to the space.

Figure 4- IQ-610

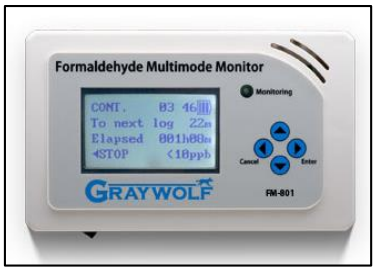


Figure 5- HCHO

5.5 Plants

The plant selected for the experiment is the Corn Cane plant. This plant is a type of plant that is usually found within residential homes. The plant does not take up too much space and does not cause any irritation to the occupants around it. The edges of the plants are not pointy, and it has not been found to be poisonous. The plant's maintenance and keep up is very simple. It requires a low amount of exposure to sunlight and a low amount of water in order to survive. The selection of a plant which has lower maintenance requirements aids the ease at which the office

management can take on the addition of plants and ensures that it is not a burden. Additionally it is important to select a plant which can confidently live on within the space. The longevity of the plant ensures that offices feel that the amount of money invested is well worth the return.

The Corn Cane plant will be introduced to each of the spaces (A,B and C). Each of the spaces will receive three plants, resulting in a total of nine plants added to the offices. When determining the amount of plants required, it was important to select a number of plants that is acceptable for an office setting. Having too many plants would be a distraction to the employees and can have a negative effect on the concentration and worker efficiency. On the other hand, having too little plants can bare a lack of results.

Although all of the spaces are somewhat enclosed, and have 3 to 4 people within then, there is still a variation in the plant to space ration achieved.

Space A: The addition of three plants to the pace resulted in a ratio of **5.25m²/plant**

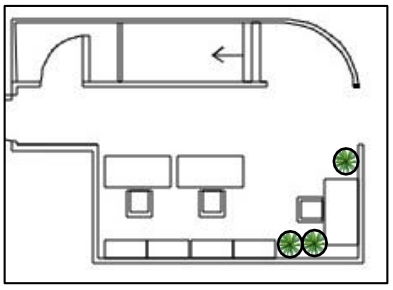


Figure 6- Space A with Plants

Figure 7- Space A with Plants Image

Space B: The addition of three plants to space B (the smallest space) resulted in the highest space to plant ratio of **3.75m²/plant**

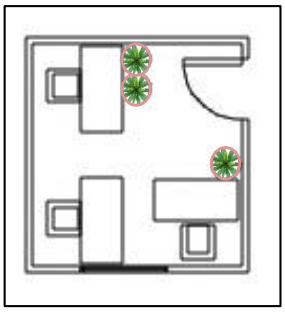


Figure 8- Space B with Plants

Figure 9- Space B with Plants Image

Space C: The addition of the three plants to Space C (the largest space) resulted in the lowest space to plant ratio of **7.166m²/plant**

Figure 10- Space C with Plants

Figure 11, 12 - Space C with Plants Images

5.6 Limitations

When conducting an experiment in place of work there are certain limitations associated with it.

The first limitation is the dynamic nature of the office setting. The occupants of the space move around throughout the office over the hours of the day. Additionally visitors, business meetings and deliveries are made throughout the day which keeps the space's environment dynamic.

In addition to this, although occupants of the space were made aware of the experiment at hand it is difficult to ensure that they do not take part in activities during the span of a month that might impact the results, activities such as opening the window, spraying perfumes and so on.

As the occupants were made aware of the research conducted it is a challenge to ensure that their survey results shared are accurate and not swayed by their perception of what should be the result. Human psychology plays a factor in their need to give results which adhere to the researcher's goals.

The last limitation faced was the attempt to maintain the temperature and relative humidity within the space. The temperature within the space was set to 23 degrees during the entire month of the experiment, in order to ensure a constant temperature throughout. Although regular spot checks were conducted this could have been altered. Therefore the attempt to maintain a constant temperature and relative humidity added to the possible limitations.

6 Analysis and Discussion

6.1 Space A

This space located on the ground floor of the office had an area of 15.75 m². There was a total of 3 occupants within the space and a total of three desks within the space as well.

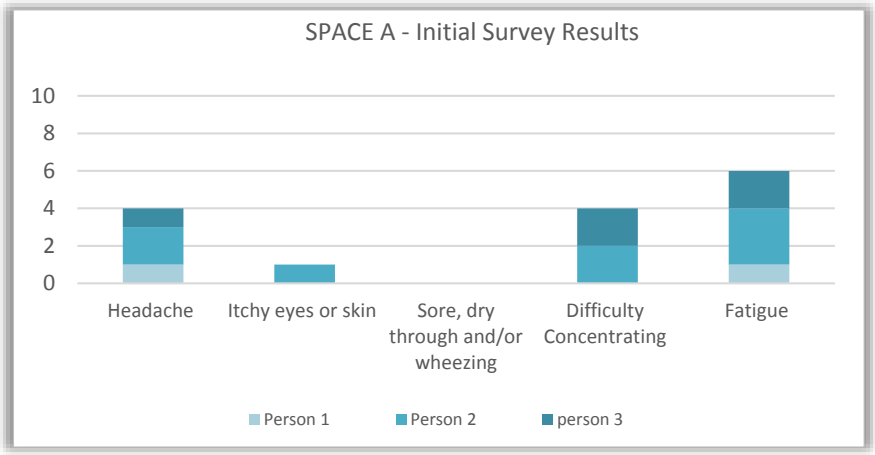
The initial results of testing for methods 1,2 and 3 showed the following:

The temperature of the room was at 23.3 degrees Celsius, which is well within the thermal comfort levels. The relative humidity of the room was at 64%.

The formaldehyde data collection setup was done from 8am to 9am. The continuous data collection took place from 9am to 7pm. The results showed the formaldehyde levels at 0.069 ppm. As compared with the Dubai Government standard for maximum acceptable limit of of 0.08ppm, the results of space A proved to be acceptable but well aligned towards to higher end of the scale.

The survey results, as shown in table 5, of the 3 occupants within Space A. Prior to the introduction of the plants to the space, the occupants had experienced headaches while at the office over the previous 2 weeks. There was a minimal amount of itchy eyes or skin, which was felt at a minor level by one person. As for the sore dry throat, none of the occupants of the space complained of such conditions. Difficulty concentrating and fatigue, both associated with productivity levels showed high results. This expressing that the occupants of the space had felt distracted during the previous 2 weeks.

Table 15 - Space A - Initial Survey Results



Three Corn Cane plants were introduced to Space A, and were left within the space for 1 month. The plants were introduced to the space at a space to plant ratio of **5.25m²/plant**. Once the one

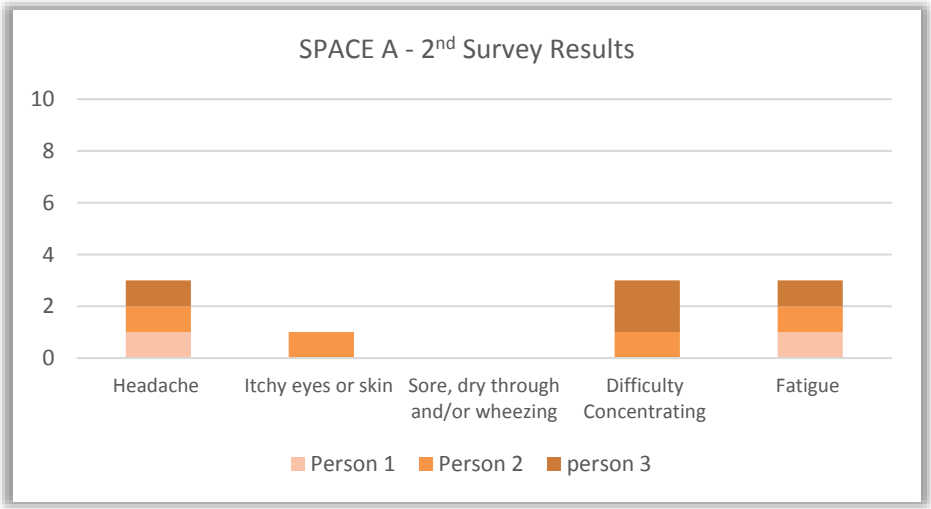
month period was completed a second round of data collection was introduced in order to collect the results.

Method 1 was utilized to collect the temperature, at 23.1 degree Celsius and the relative humidity, at 64.4%. When compared to the results attained one month earlier, the temperature, which had been 23.3 degrees Celsius had dropped a mere 0.2 degrees Celsius. This temperature drop is at a very low rate and its possible effect or interference on the formaldehyde levels is rare to none. The relative humidity on the other hand increased from the originate rate of 64.0% to 64.4%. The increase within the relative humidity is at 0.4%. This is also considered a low rate of change and can considered a non-threatening factor in relation to the formaldehyde results.

The formaldehyde levels were initially collected at 0.069 ppm, and after the introduction of the Corn Cane plant life to the space, the formaldehyde levels dropped 0.001 ppm, a decrease of 1.5%. This decrease in the formaldehyde levels is not a large decrease to be noted.

Overall when looking back at the results attained within space A it is observed that when the plant life is introduced to the space at a rate of 5.25 m²/plant the rate of decrease of formaldehyde levels is very low. In addition to this, the original formaldehyde where not at a high or critical presence.

As for Method 3, the reduction in health and productivity complains is evident in the results (table 6). In relation to perceived help complaints, 'headaches' were reduced by 25%, whereas



the results concerning the productivity such as 'difficulty concentrating' and 'fatigue', there was

a drop in both. 'Difficulty concentrating' dropped by 25% whereas the rate of 'fatigue' felt by the occupants of the space was reduced by 50%.

When comparing the changes in the results between the formaldehyde levels and the survey results, the formaldehyde levels were dropped by a small amount of 1.5% whereas some aspects of the survey results where improved by almost 50%. This lack of connection a between the two results leads to the conclusion that the improvement in the survey results could be directly related to the improved perceived health and productivity associated with the presence of plant life. Previous research conducted by Fjeld (2006) has shown the direct link between improvement of employee morale and the presence of plant life.

6.2 Space B

The second space, labeled as Space B, is located on the first floor. It has three occupants and three desks within the small 11.25m² room. This space is the smallest and most controlled of all the three spaces as it relies completely on the HVAC system. It does not have a window or natural ventilation.

The initial data collected was conducted prior to the inclusion of the Corn Cane plant life. Within the first method, it was documented that the temperature in the room was at 23 degrees Celsius.

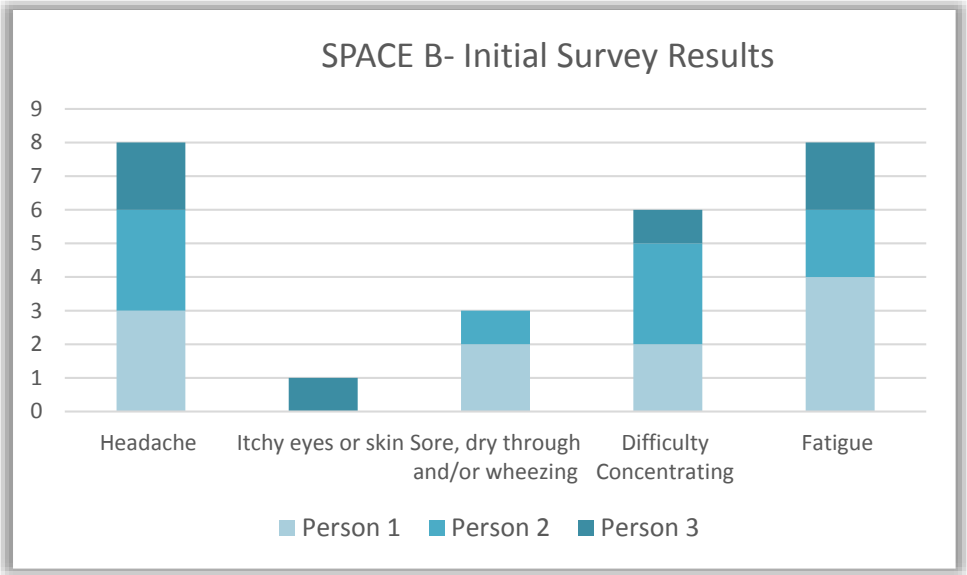
Table 16 - Space A - Secondary Survey Results

In addition the relative humidity was noted to be at 65%.

The second method of data collected concluded that the formaldehyde levels within the room are at 0.074ppm, which is significantly higher than that of Space A. It is also much closer to the maximum formaldehyde limit set by the Dubai Government Handbook.

The final method's results that reflected the discomfort which the occupants of the tight space were experiencing (table 7). All three occupants of the space complained of headaches within the last 2 weeks while in the office. Additionally all three also felt difficulty concentrating and fatigue over the last 2 weeks.

Table 17- Space B - Initial Survey Results



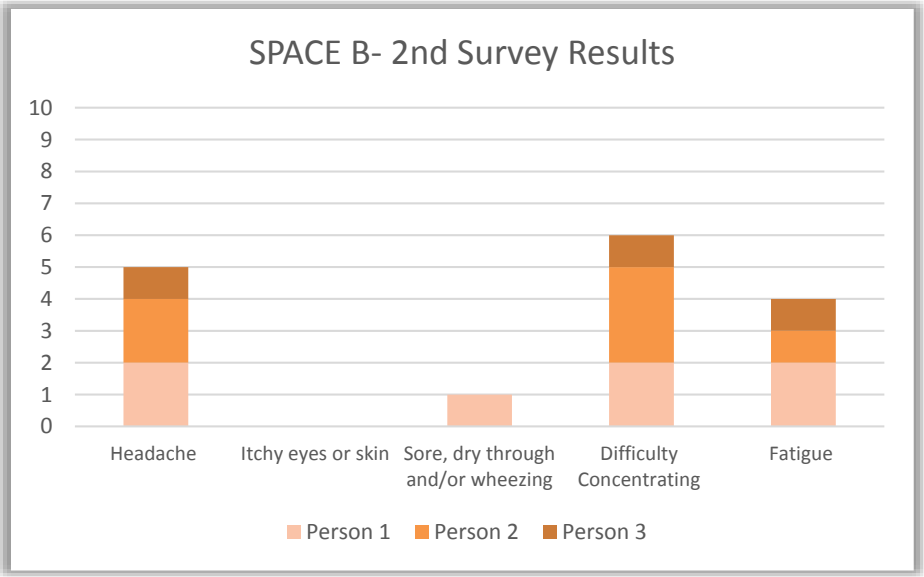
As was done with Space A, once all the data was collected the Corn Cane plant was introduced into the space. Due to the size of the space, the plant to space ratio in space B was the highest of the 3 spaces at **3.75m²/plant.**

The temperature and humidity remained relatively the same with the secondary testing. The slight variation was a drop in the temperature from 23 to 22.7 degrees Celsius. The relative humidity however remained constant at 65%.

The formaldehyde testing showed a drop from the initial 0.074 ppm to 0.071 ppm. This is a total of a 4% decrease. The decrease in formaldehyde levels is associated with several conditions which were present within this space. As mentioned, the space to plant ration was at a high rate of 3.75m²/plant. Additionally, this was the smallest space selected, and presented the highest level of formaldehyde levels to begin with. The initial level of formaldehyde was at 0.074ppm, which is relatively close to the maximum standard. Previous research (wood, 2006) has shown that a plants ability to absorb toxins increases as the presence of toxins increases.

As for the survey results, shown in table 8, there is a notable decrease in symptoms felt by the occupants of the space, but the symptoms remained present. Headaches were decreased by 37.5% but the presence of occupants suffering from headaches continues. One person had suffered from minor itchy eyes and skin but their complaint was no longer relevant in the second round. Sore, dry throat and wheezing was also decreased by 66.6%. Difficulty concentrating

Table 18- Space B- Secondary Survey Results



however remained unchanged and due to the quality of the space. This unchanged aspect could be associated with the quality of the crowded space and the lack of privacy. The last question in the survey was associated with fatigue. The fatigue levels did decrease over the span of the experiment by almost 50 percent. There was a significant improvement by the fatigue felt by each employee within the space.

The overall results for Space B showed improvements in both the formaldehyde levels and the perceived health and productivity. A total of a 4% drop in the formaldehyde levels of the space was achieved. The survey results also showcased an improvement of the employee perceived health and productivity levels.

6.3 Space C

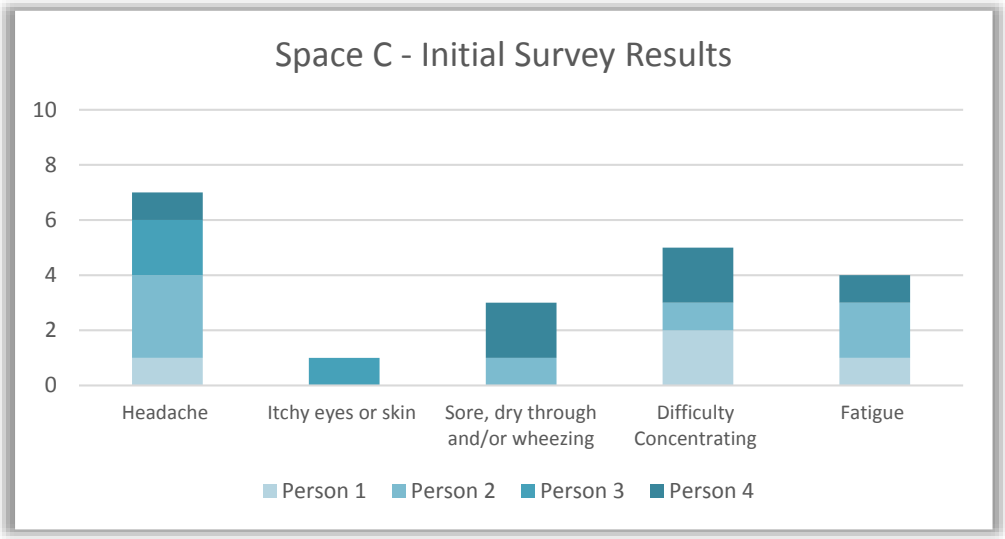
Space C was the largest of the threes spaces and encompasses 4 employees within the space. The space also has a window that is a source of direct sunlight. Occupants of the space were asked to keep the window close in order to minimise its effect on outcomes.

The initial data collected shower the temperature at 23 degrees Celsius and relative humidity at 66.0%. This being the highest amount of humidity between all the three spaces.

The formaldehyde levels where recorded at 0.070ppm. The results of formaldehyde were 0.01ppm away from the maximum allowed quantity, but this was the second highest concentration recorded between the three spaces. The survey results showed that all four

occupants complained of headache symptoms during the last 2 weeks. Additionally all four occupants complained from the occasional inability to concentrate while at the office.

Table 19- Space C - Initial Survey Results



The secondary round of testing began a month after the Corn Cane plant was introduced to the space. The plant life was introduced at a rate of **7.166m²/plant**, this being the lowest rate of space to plant ratio.

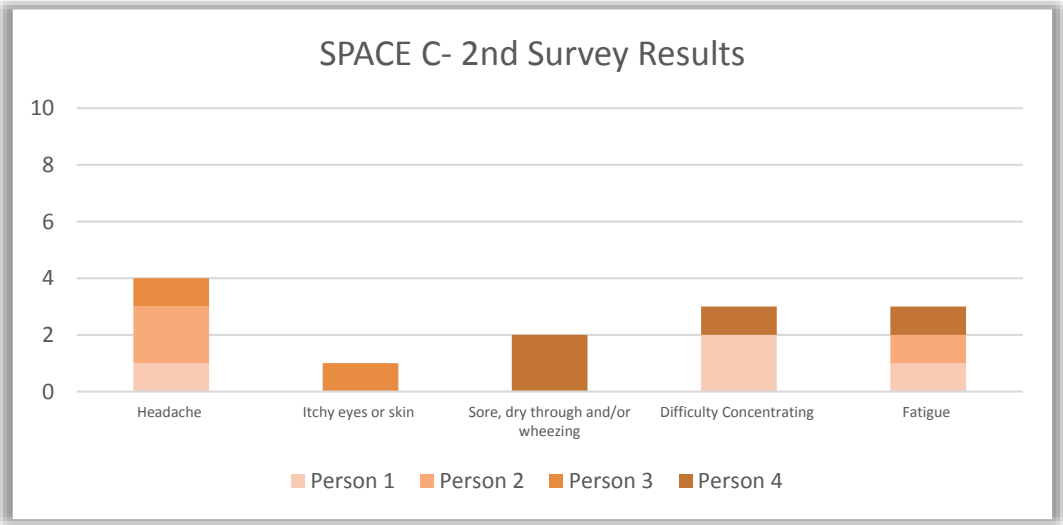
Both the temperature and relative humidity had increased. The temperature increased by 0.2 degrees Celsius whereas the relative humidity increased by 1.2% to reach 67.2%. This increase in both the temperature and relative humidity was concerning as an increase similar to this could have effects which alter the results of the formaldehyde testing.

The results of the formaldehyde data collection is that the formaldehyde concentrations increase by 0.001ppm. This adds up to a 1.4% increase in concentration. Factors which could have contributed to the increase within the formaldehyde levels are, as mentioned earlier, the increase in temperature and relative humidity. A second aspect which could have led to the increase in formaldehyde levels is the size of the space and the low plant to space ratio. The low ratio could prevent the plants from reducing the formaldehyde levels.

Although the formaldehyde levels increased during the period of the month, the survey results continued to be positive. Employees had significant drops in headaches, sore throat, difficulty concentrating and fatigue. As seen in table 10, four out of the five possible symptoms where decreased. The employees felt a sense of comfort when the plants were introduced to the space. This comfort is

not associated with the rate of formaldehyde emissions. Instead the rate of comfort was directly linked to presence of plantlife.

Table 20 - Space C - Secondary Survey Results



6.4 Overall Results

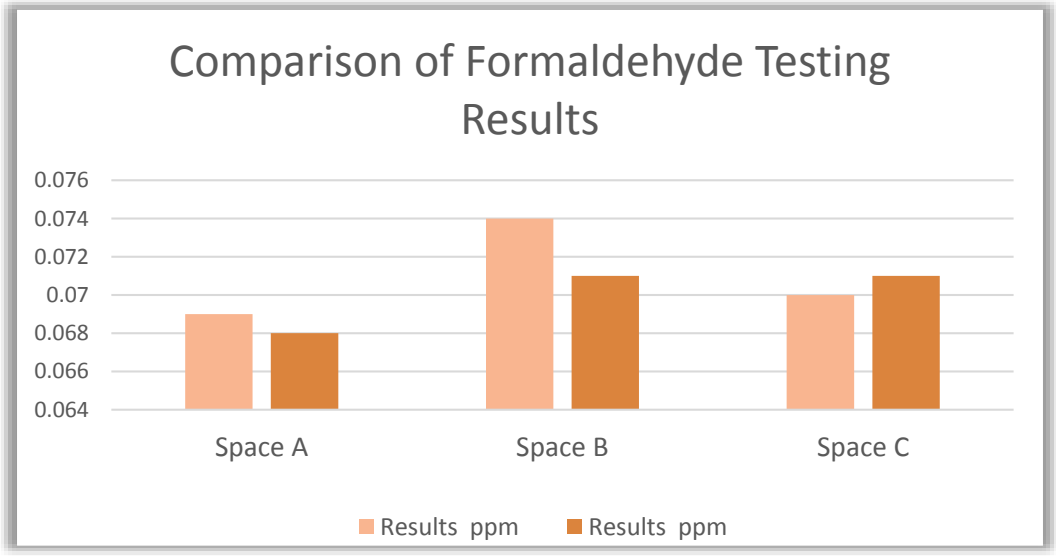
The initial aim of this study was to look at the impacts of plant life on the formaldehyde levels within an office set in the UAE. When looking at the below (table 11) results in relation to the spaces selected there is a notable impact that has been made on the Space B formaldehyde levels.

The characteristics of Space B provided the ideal situation in which the plants were able to impact the space at the greatest rate; characteristics such as, the smaller and more controlled space with a high density of occupants and formaldehyde emissions.

Plant life was able to absorb the greatest amount of formaldehyde levels when the greatest amount was present. They were able to help reduce the levels of formaldehyde from 0.074ppm to 0.071ppm, a total reduction of 4%.

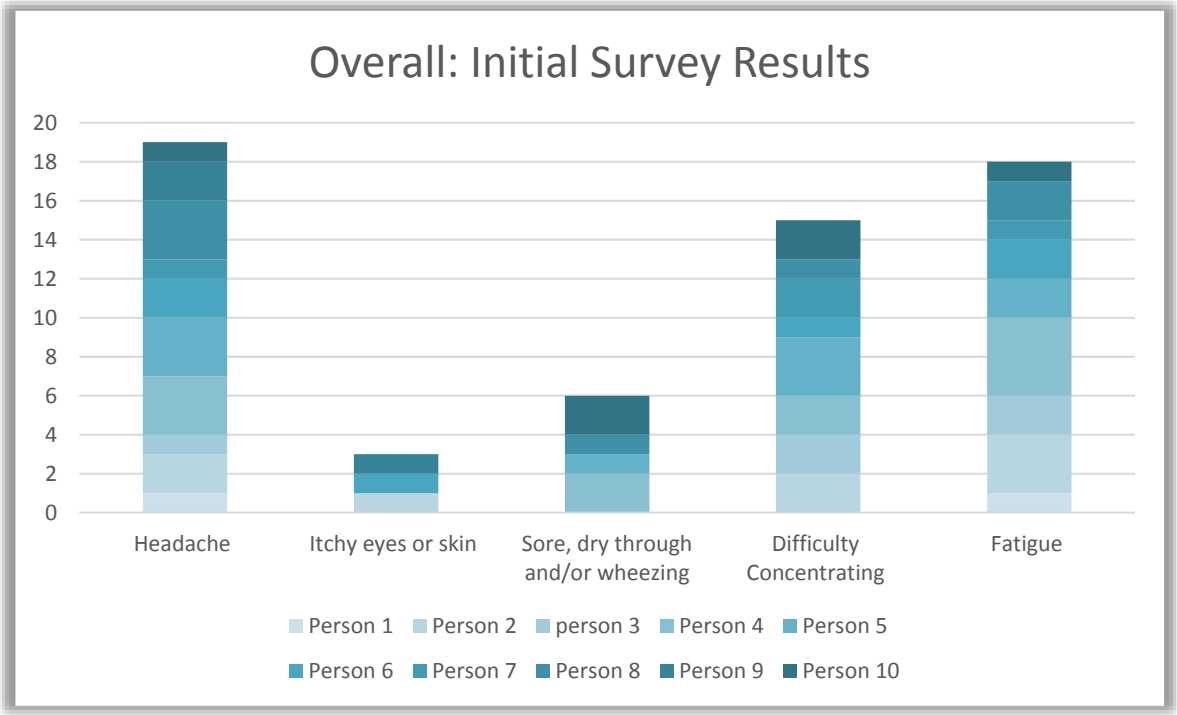
The two remaining spaces had minimal changes occurring to the formaldehyde levels. The lack of changes could be associated with three factors. The first being the low initial formaldehyde levels, as low formaldehyde emissions give the plants little to absorb. The second is the change in temperature and humidity which could have particularly impacted space C (where the largest change in relative humidity occurred). The thirst aspect is the size of the spaces, which created a low space to plant ratio.

Table 21- Overall Formaldehyde Results



The results of the surveys showed a drastic improvement. The initial survey results showed that the majority of the employees had suffered some of the perceived health symptoms over the previous two weeks. Although the symptoms where not drastically noted (example: daily headache), the presence of such symptoms were still occurring.

Table 22- Overall Initial Survey Results



As seen in the initial results table 12, 100 percent of the employees suffered at headache within the two weeks prior to the date in which the initial survey was conducted. The majority of headaches were noted to be regular occurrences that were present several times a week. Headaches were the most frequently mentioned in terms of the perceived health aspect of the survey. The other perceived health questions, itchy eyes or skin, and sore, dry throat and or wheezing, received minimal association.

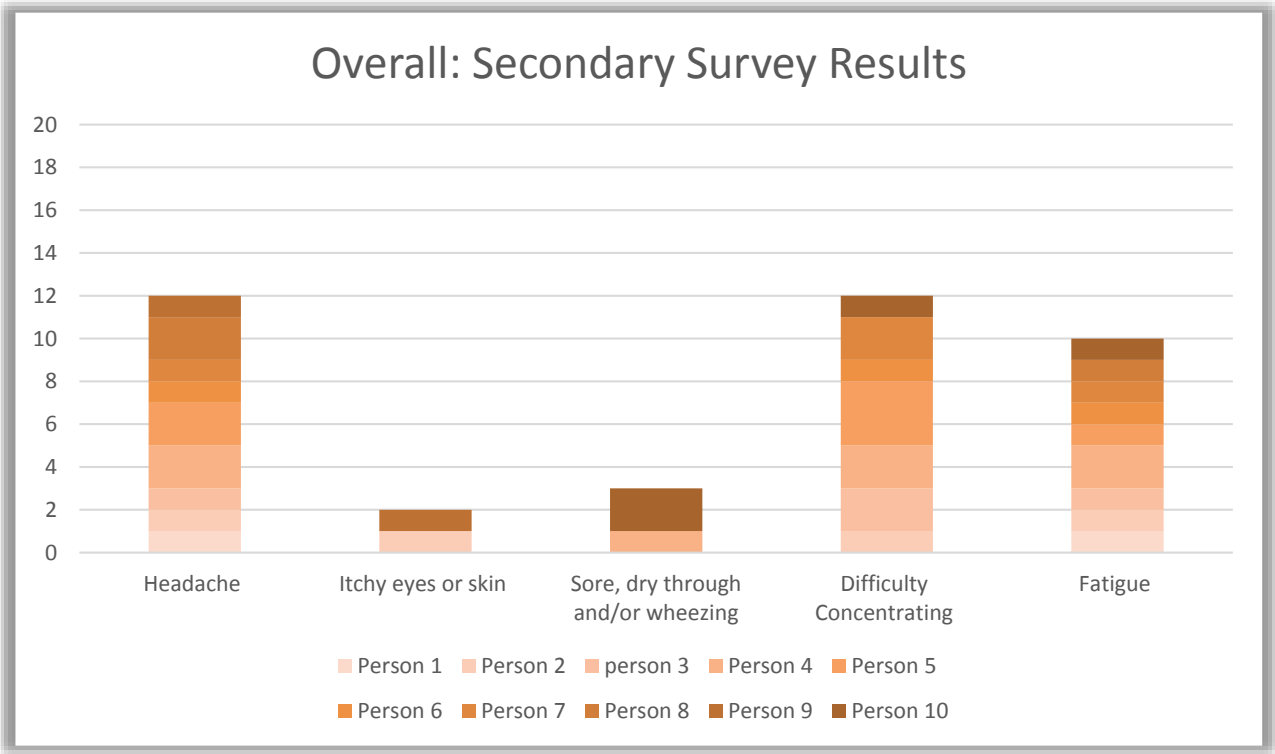
When looking at the perceived personal productivity, the majority of the office felt difficulty concentration. A rate of 80% and 90% percent mentioned a feeling of fatigue sometime during the last 2 weeks.

After the Corn Cane plant was introduced to the space (table 13) it is noted that 80 percent of the office had experienced a minor headache at some point during the previous two weeks. This showed a drop of 36% of headache symptoms. There was a similar drop of 33% in the category of itchy eyes and skin. As

for sore throat, cough and or wheezing, it was dropped by 50%. When looking at the overall results related to the perceived health of the employees, there is an overwhelming improvement.

When comparing the results of the perceived productivity, a drop of 20% was achieved. As for the general feeling of fatigue, it was reduced by a total of 44%.

Table 23- Overall Secondary Survey Results



The above results and improvement in employee perceived health and productivity far out way the results which were achieved by the decrease in formaldehyde concentrations. This leads to the conclusion that the plant life in itself is having positive effect on the employees. The psychological impacts of plants and plant life have been shown in previous research. Smith et al. (2009) showed that the ability of plant life to improve the in-office moral far outweighed the results achieved of the plants reducing the amount of toxins present.

7 Conclusion

This initial aim of this research was to look at the impacts of plant life on formaldehyde levels within an office set in the UAE. Formaldehyde is a toxic VOC that is present in our environment. It is produced naturally through volcanic eruptions and any combustive activity. The levels of formaldehyde however have increase over the last 40 years due to the inclusion of it as a resin within furniture, finishes and insulation. This high presence of formaldehyde within interior spaces poses a health risk to the occupants involved.

Offices are commercial environments in which furniture is selected based on financial requirements. Therefore the majority of offices within the UAE opt to purchase MDF wood desks, shelving units and so on. These types of furniture pieces, although more affordable contain a higher amount of resin within the fiberboard to help merge the pieces together. This resin contains a very high rate of formaldehyde and therefore emits formaldehyde into the space at high concentrations.

Additionally, offices within the UAE have become interior spaces which have the greatest reliability on HVAC systems. In many of the high-rises and office buildings, there are no window which can be opened therefore people have no option but to rely on the HVAC system available.

The average office worker is not keen to complain or bring attention to their personal discomfort while at the office. If a person were to feel regular headache or any other symptoms associated with sick building syndrome, it is likely that the person will dismiss these symptoms and associate them with their own personal lifestyle or stress.

After the literature review was conducted the Corn Cane plant was selected as the plant with the most suitable qualities to be incorporated into an office setting. The plant had previously proven its ability to absorb and relieve a space of formaldehyde emissions, (Sustainable Baby Steps n. d.). The Corn Cane plant is also a low maintenance plant to be included into an office. This is ideal as the office management will be able to carry forth with maintaining the plant with a reduced risk of it dying. The plant required low light and consumed water at a low rate. The leaves of the plant are not too large and do not take up a large space within the office. The plant itself does not have any pointy edges or harmful features. Based on the above it was the best plant to proceed with.

The initial data collection results of the office space that was selected showed that the levels of formaldehyde within the office were relatively high but still not reaching the maximum concentration of

0.08ppm. The survey results however showed that the occupants of the space suffered headaches regularly, an inability to concentrate within the spaces, as well as a general feeling of fatigue.

The plant life was introduced for a period of one month, after which the data collection process began again. The formaldehyde levels showed a decrease of 4% when the plant life was introduced to the space at a highest level of formaldehyde (space B), as well as the highest space-to-plant rations of 3.75m²/plant. The space was also an enclosed space that had the most controlled environment. Leading to the conclusion that the results of formaldehyde reduction from a space are increase when the presence of formaldehyde is greater. Additionally, formaldehyde levels are reduced at a more optimized rate when the space to plant ratio is increased.

When looking at the overall survey results collected. There is a significant improvement in the office moral. The employees feel an improved sense of perceived health and productivity. This is paralleled through the results which show a decrease in symptoms previously felt within the space. The results also showed a 20% decrease in an inability to concentrate within the space as well as a 44% decrease in a feeling of fatigue while at the office.

The space with the most improved survey results was Space C. Employees within this space experienced an improvement across all of the questions posed over the survey. Which proved to be an interesting result, as space C had the least improved level of formaldehyde. In fact, space C saw an increase of formaldehyde levels by 1.4%.

The lack of connection between formaldehyde level improvement and survey results shows that the perceived health and productivity levels are not connected to the formaldehyde levels. On the contrary the perceived health and productivity levels were directly associated with introducing the plants life into the space.

These results showcase the extent at which plant life was able to impact the occupants of the space whether or not the formaldehyde levels were decreased. Therefore the impact of the plant life on the space was far greater than that of the reduced formaldehyde levels. The psychological impacts of the presence of plant life on the occupants of the space gave them an improved perception of their health and productivity.

8 Recommendations

Future recommendations to the application of testing on formaldehyde levels would be to ensure greater control on the various dependable variables. Various aspects of the study need to be controlled in order to ensure that the results achieved are precisely accurate

The first item which needs to be controlled is the temperature and relative humidity. Firstly identify and maintain a constant level of temperature and humidity. Temperature and humidity play a key role in the increase or decrease of formaldehyde levels. Therefore to ensure that the independent variable is the only variable causing change in formaldehyde levels, these two aspects must be controlled

The second recommendation is to seek out a space with a formaldehyde concentration of 0.1ppm or greater. As noted by the research the space with the highest amount of formaldehyde levels was able to achieve the best reduction results. Therefore future research should aim to push these boundaries and present an even higher concentration in order to fully establish the plant's capability of reducing the toxin.

The third and final recommendation for future research on the impacts of plant life on formaldehyde levels is for the experiments to be conducted within a controlled environment as the control of the environment also allows for more accurate results.

A recommended environment for future research to take place would be that of a lab environment. A lab environment allows researchers to control the temperate and relative humidity. It is also a means of controlling and increasing the formaldehyde levels to be increased over the rate of 0.1ppm. And finally it is an ideal controlled environment with minimal interruptions which were found in a dynamic office setting.

9 References

An Update on Formaldehyde. U.S. EPA (2015 - Revised)
http://www.epa.gov/iaq/pubs/formald2.html

ASHRAE Standard (2007) *Ventilation for Acceptable Indoor Air Quality. Standard 62.1-2004* [Online]. Available at:*file:///C:/Users/PC%20Moe/Downloads/20070518_6212004_addh.pdf* (Accessed: 10th January 2015).http://journal.ashspublications.org/content/133/4/521.full

Costa P. (2000) 'Plants Improve Qir Quality and Cut Energy Consumption, Reports International Scientific Conference', *Facilities* , 18(3/4), pp. [Online]. Available at:*http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/f.2000.06918cab.019*(Accessed: 15th December 2014).

Dubai Government (2011) *Green Building Regulations & Specifications.* [Online]. Available at:*http://login.dm.gov.ae/wps/wcm/connect/775faf8047238af88090d1025fdb7352/DM+ENG+BOOK+FINAL_Low.pdf?MOD=AJPERES* (Accessed: 10th January 2015).

Fjeld T. (2000) 'Plants Improve Qir Quality and Cut Energy Consumption, Reports International Scientific Conference', *Facilities* , 18(3/4), pp. [Online]. Available at:*http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/f.2000.06918cab.019*(Accessed: 15th December 2014).

Giese M., Bauer-Doranth U., C. Langebartels and H. Sandermann Jr (1994) 'Detoxification of Formaldehyde by the Spider Plant (Chlorophytum comosum L.) and by Soybean (Glycine max L.) Cell-Suspension Cultures', *Plant Physiology* , 10(4), pp. 1301-1309 [Online]. Available at:*http://www.plantphysiol.org/content/104/4/1301.abstract?ijkey=9d90566b832d93e10e29bf6da67e8dfcbbd1bbdf&keytype2=tf_ipsecsha*(Accessed: 15th December 2014).

Godish T, *Indoor air Pollution Control* (1989)

IEQ Indoor Plants (n. d.) *Benefits of Indoor Plants*. http://www.ieqindoorplants.com.au/indoor-plant-resource-library/benefits-of-indoor-plants/. Accessed on March 3rd, 2015

Illinois Department of Public Health (2011) *Illinois Department of Public Health Guidelines for Indoor Air Quality,* Available at:*http://www.idph.state.il.us/envhealth/factsheets/indoorairqualityguide_fs.htm* (Accessed: 2nd December 2014).file:///C:/Users/PC%20Moe/Downloads/20100608_62_1_2007_q_final.pdf

Kim S. E. (2014) 'Physical Workplace as a Strategic Asset for Improving Performance in Public Organizations', *Administration & Society* , 46(5), pp. 496-518 [Online]. Available at: *http://aas.sagepub.com.ezproxy.buid.ac.ae/content/46/5/496.abstract* (Accessed: 2nd December 2014).http://link.springer.com/article/10.1023/B:WATE.0000038896.55713.5b#page-1

n.a (2003) *Indoor Air Pollution: An Evaluation of Three Agents,* Available at:*http://enhs.umn.edu/current/5103/air/intro.html* (Accessed: 2nd December 2014).

n.a (2003) *Formaldehyde* , Available at:*http://enhs.umn.edu/current/5103/air/formaldehyde.html* (Accessed: 2nd December 2014).

Oyabu, T., Sawada, A., Onodera, T., Takenaka, K. and Wolverton, B. (2003), "*Characteristics of potted plants for removing offensive odors*", *Sensors and Actuators B: Chemical*, Vol. 18 No. 1, 1 March, pp.131-6. [CrossRef], [ISI] [Infotrieve]

Raw GJ et al. *Exposure to air pollutants in English homes*. Journal of Exposure Analysis and Environmental Epidemiology, 2004, 14:S85–S94

Smith A., Pitt M., (2009) 'Sustainable workplaces: improving staff health and well-being using plants', *Journal of Corporate Real Estate,* 11(1), pp. 52-65 [Online]. Available at:*http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/14630010910940552*(Accessed: 15th December 2014).

Wolverton B.C., Wolverton J.D. (2000) 'Plants and Soil Microorganisms', *Journal of the Mississippi Academy of Sciences* , (), pp. 11-15 [Online]. Available at:*http://www.wolvertonenvironmental.com/MsAcad-93.pdf* (Accessed: 15th December 2014).

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 & Biotechnology* , 77(1), pp. 120-129 [Online]. Available at:*http://cat.inist.fr/?aModele=afficheN&cpsidt=13431444* (Accessed: 10th December 2014).

Wood R. (2000) 'Plants Improve Qir Quality and Cut Energy Consumption, Reports International Scientific Conference', *Facilities* , 18(3/4), pp. [Online]. Available at:*http://www.emeraldinsight.com.ezproxy.buid.ac.ae/doi/full/10.1108/f.2000.06918cab.019*(Accessed: 15th December 2014).

Yeatts K. B., El-Sadig M., Leith D., Kalsbaek W., Al Maskari F., Couper D., Funk W. E., Zoubeidi T., Chan R. L., Trent C. L. Davidson C. A., Boundy M. G., Kassab M. M., Hasan M. Y., Rusyn I., Gibson J. M., Olsha A. F. (2012) 'Indoor Air Pollutants and Health in the United Arab Emirates', *Environmental Health Perspectives* , 120(5), pp. 687-698 [Online]. Available at:*http://www.indiaenvironmentportal.org.in/files/file/Indoor%20Air%20Pollutants.pdf*(Accessed: 10th December 2014).