Common Indoor Plants and Their Contribution to Clean Air - Does Adding Indoor Plants to New Office or Residential Buildings Reduce the Amount of Air Pollution?

by

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Abstract

Background: Formaldehyde, acetone, and styrene are three volatile organic compounds (VOCs) shown to cause serious health effects. This study sought to determine the health effects and levels of these VOCs and determined if their levels decreased after the addition of indoor plants.

Methods: Two offices were tested in a newer building and two offices were tested in an older building. The chemical levels were tested before plants were added and were retested after plants were added at four and six weeks.

Results: In the new building, formaldehyde increased by the fourth week, but decreased by the sixth week, while acetone decreased by the fourth week and increased by the sixth week. In the older building, acetone increased by the fourth week and decreased by the sixth week. Formaldehyde decreased by the fourth week and increased by the sixth week. No styrene was found in any office at any time.

Conclusion: Employees may become exposed to VOCs in office buildings. As healthcare providers, nurses can educate people about what these harmful chemicals are and ways to reduce exposure. Nurses can also introduce efficient methods, such as adding plants, to decrease these chemicals in the places where people spend the most time.

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Table of Contents

Introduction

People in the United States spend approximately 90% of their time indoors (Environmental Protection Agency [EPA], 2011). Typically, indoor environments include office buildings or places of residence. With the awareness that the majority of time is spent indoors and the increasing realization that some hazards may arise from these indoor environments, researchers are becoming increasingly concerned with how these environments and potential hazards could be affecting the population's health status. A major concern involves the air that people are continually breathing in and what chemicals might be interfering with adequate air quality. If there are harmful chemicals in the air, then every time a person inhales, potentially harmful substances could be presented directly into the body. This could be extremely detrimental to many populations and can also be dependent upon many circumstances. According to the EPA (2012a), VOCs are emitted as gases and can be released from either liquids or solids. Furthermore, the EPA mentions that VOC levels can be up to ten times higher indoors when compared to outdoors. Formaldehyde and styrene are two VOCs that are listed as known carcinogens and, along with acetone, have shown to cause other serious health effects (Aydogan & Montoya, 2011; Wongvijitsuk, Navasumrit, Vattanasit, Parnlob, & Ruchirawat, 2011). They are also constituents in what has been termed, "sick building syndrome" or SBS (Redlich, Sparer, & Cullen, 1997), which refers to numerous non-specific complaints from the people who are exposed to these chemicals. With this emerging information, it is vital to discover efficient and cost-effective ways to remove these VOCs from the places where we spend the most time.

According to Sclanders (2010) who sought to identify Nightingale's theoretical conceptual base, "environment is the umbrella concept in the Nightingale theory of nursing. It was her contention that the environment could be altered in such a manner as to improve conditions so that the natural laws would allow healing to occur" (p. 84). With the use of this nursing model, nurses can be advocates for the people that work in new buildings and ensure that they take necessary precautions to be healthy by paying attention to not only the internal elements of their health, but also the external ones. The addition of indoor plants has been shown to greatly decrease the amount of VOCs in indoor air, thus, reducing the health risks to the people exposed to them (Xu, Wang, & Hou, 2011). This new knowledge can be used as a preventative measure by health care providers when teaching about environmental health risks and hazards and how to keep these VOCs at a minimal risk.

Review of Literature

Formaldehyde - What Is It and Where Is It?

Formaldehyde is a chemical found in indoor air that is commonly used during the manufacture of building materials and various household products (EPA, 2013a). Formaldehyde is a colorless gas with a strong odor that can be smothering at room temperature (EPA, 2013a). The chemical formula for formaldehyde is CH_2O and is readily soluble in water at room temperature (EPA, 2013a). According to Aydogan and Montoya (2011), "people are exposed to environmental formaldehyde from wood-based products, wall coverings, rubber, paint, adhesives, lubricants, cosmetics, electronic equipment, and combustion" (p. 2676). Formaldehyde is also found in carpet, curtains, and paper products (Kim et al. 2008). These materials are used frequently and universally when constructing new buildings and during the manufacturing process. According to the EPA (2013a), higher amounts of formaldehyde can be found in indoor air and can typically be found in newer manufactured homes. Xu, Wang, and

Hou (2011), also found that "newly built or remodeled residences are often found to release high levels of indoor formaldehyde" (p. 314), while Aydogan and Montoya (2011), disclosed that "levels of formaldehyde generally decrease with the products age" (p. 2676). Formaldehyde is associated with serious indoor pollution and although the levels generally decrease over time, ten years according to Wolverton and Wolverton (1996), that is still too much time for people to be exposed to and breathing this chemical into their lungs.

What are the Health Hazards of Formaldehyde?

In a study performed by Xu, Wang, and Hou (2011), the researchers determined that formaldehyde may cause irritation, allergic asthma, neurasthenia, and may generate genotoxicity and carcinogenesis. Headache, nausea, dizziness, eye irritation, mucous membrane and respiratory irritation, drowsiness, fatigue, and general malaise are components of sick building syndrome that are often caused by formaldehyde exposure (Aydogen & Montoya, 2011). Other effects seen from exposure to formaldehyde in humans are coughing, wheezing, chest pains, and bronchitis, eye, nose, and throat irritation, lesions in the respiratory system from chronic inhalation exposure to formaldehyde, and an increased incidence of menstrual disorders observed in female workers using urea-formaldehyde resins (EPA, 2013a). The health effects associated with formaldehyde exposure can range from being slight annoyances to life threatening conditions. Formaldehyde has been reported to cause long term effects including cancer, genotoxicity, congenital anomalies, premature birth, low birth weight, leukemia in children, and Alzheimer's disease (Aydogan & Montoya, 2011; Agency for Toxic Substances and Disease Registry [ATSDR], 2011). A chart containing the short-term and long-term health effects of formaldehyde can be found on page 12.

Styrene - What Is It and Where Is It?

Styrene, with a chemical component of C_8H_8, is a sweet-smelling colorless liquid (EPA, 2013b). Roder-Stolinski et al. (2008) reported that styrene is a colorless liquid that eventually evaporates, mainly being used in the manufacture of rubber and plastics and is a component of packing and insulation materials, fiberglass, pipes, carpet backing, and paints. They also reported, "due to the volatility of this compound, the dominant route of styrene exposure for the average population is inhalation of contaminated indoor air" (Roder-Stolinski et al., 2008, p. 241). According to the EPA (2013b), people are mainly exposed to styrene via indoor air. This chemical is used primarily during the production of polystyrene plastics and resins.

What are the Health Hazards of Styrene?

In the study performed by Roder-Stolinski et al. (2008), the researchers determined that styrene exposure mainly occurs through inhalation; therefore, lung epithelial cells are primarily involved with the toxic and inflammatory responses. They also disclosed that various studies involving humans reported that after inhalation of styrene, the chemical quickly enters the body tissues (Roder-Stolinski et al., 2008). This exposure can lead to various health conditions involving the neurological system including depression, concentration issues, and tiredness, and other health issues including muscle weakness, nausea, throat irritation and eye irritation (Roder-Stolinski, 2008). The EPA (2013b) reported numerous short term health effects caused by the exposure to styrene including respiratory and gastrointestinal effects, mucous membrane and eye irritation, as well as long term effects, including headache, fatigue, weakness, depression, CNS dysfunction (including reaction time, memory, visuomotor speed and accuracy, and intellectual function), hearing loss, peripheral neuropathy, minor effects on some kidney enzyme functions and on the blood and an increased frequency of spontaneous abortions. The EPA (2013b) also reported a possible increased cancer risk with exposure to styrene including lymphoma and leukemia, however, these results were inconclusive due to inadequate information. In a study performed by Wongvijitsuk, Navasumrit, Vattanasit, Parnlob, and Ruchirawat (2011), the researchers found that styrene is a known mutagen and possible human carcinogen. Through the process of activation of styrene in the body, they also revealed that DNA strand breaks, sister-chromatid exchanges, and alterations in the defense mechanisms such as the antioxidant system and DNA repair process have occurred with exposure to and activation of styrene (Wongvijitsuk et al., 2011). Styrene has a multitude of possible health hazards, and with this emerging information, it has become vital that ways to combat these health effects are discovered. A chart containing the short-term and long-term health effects of styrene can be found on page 12.

Acetone - What Is It and Where Is It?

"Acetone, a colorless, highly volatile, flammable liquid with a mildly pungent odor is a high volume chemical that is used as an intermediate in the production of methylacrylates, Bisphenol A, and other ketones, and as a solvent for different applications such as coatings, printing inks, adhesives, cleaning material, and in spinning and film casting processes" (Arts, Mojet, Gemert, Emmen, Lammers, Marquart, Woutersen, & Feron, 2002, p. 44). In another study conducted by Kumagai, Matsunaga, and Tabuchi (1998), the researchers reported that acetone is an endogenous constituent, meaning that it is already found in the body, and is a metabolite of fatty acid. At high exposure levels, however, acetone can be toxic to the central nervous system (Kumagai, Matsunaga, and Tabuchi, (1998). Unlike formaldehyde and styrene, acetone is not labeled as a known carcinogen as reported by the Agency for Toxic Substances and Disease Registry, (ATSDR, 2011). Although acetone was found to cause many health related issues, various researchers did not find acetone to be genotoxic or mutagenic (Arts et al., 2002). Once acetone is inhaled, it is rapidly absorbed into the respiratory tract (Arts et al., 2002). After absorbed, it is distributed among non-adipose tissues and then excreted from the body via liver metabolism and excretion (Arts et al., 2002). Arts et al. (2002) also mentioned that the major excretion route of acetone is via exhalation of CO_2. According to Arts et al. (2002), “the lowest acetone exposure concentration found to be irritating to the respiratory tract and eyes ranges from about 250 to 186,000 ppm” (p. 43).

What are the Health Hazards of Acetone?

As mentioned previously, acetone is not labeled as a carcinogen and is not considered to be genotoxic (Arts et al., 2002). Acetone does, however, have other health effects that can be bothersome and even dangerous. The Centers for Disease Control and Prevention (CDC) reports that exposure to acetone can lead to eye, nose, and throat irritation, headache, dizziness, dermatitis, and central nervous system depression (2010). Arts et al. (2002) found that when workers were exposed acutely to acetone levels that were above 12,000 ppm for 4 hours, they would experience dizziness, unsteadiness, confusion, headache, and even unconsciousness. With levels ranging from 250 to 1000 ppm and 2500 to 8000 ppm, the workers reported irritation of the eyes, nose, and throat (Arts et al., 2002, p. 44). A chart containing the short-term and long-term health effects of acetone can be found on page 12.

Sick Building Syndrome

According to Redlich, Sparer, and Cullen (1997), SBS refers to various complaints that are non-specific, including eye irritation, throat irritation, coughing, wheezing, shortness of breath, headaches, fatigue, lack of concentration, rash, pruritus, skin dryness, enhanced odor perception, and visual disturbances. Other symptoms of SBS include nausea, dizziness, drowsiness, and general malaise (Aydogan & Montoya, 2011). Short and Long Term Effects of Formaldehyde, Styrene, and Acetone have been summarized in Table 1. These symptoms are very broad and could be related to exposure to formaldehyde, styrene, acetone or any other volatile organic compound. This wide range of symptoms could be caused by indoor air pollutants that people may be exposed to for a prolonged amount of time for the chronic health effects or for a short amount of time for the acute health effects. Redlich, Sparer, and Cullen (1997), also disclosed that indoor exposure to noxious stimuli hazards occur at low levels and a typical SBS environment is a new or newly remodeled building with a heating, ventilation, and air conditioning system.

Table 1: Short and Long Term Effects of Formaldehyde, Styrene, and Acetone

CHEMICALS	**SHORT-TERM HEALTH EFFECTS**	**LONG-TERM HEALTH EFFECTS**
Formaldehyde	Irritation, allergic asthma, headache, nausea, dizziness, eye irritation, mucous membrane and respiratory irritation, drowsiness, fatigue, general malaise, coughing, wheezing, chest pains, bronchitis, eye, nose, and throat irritation	Neurasthenia, genotoxicity, lesions in the respiratory system, cancer, congenital anomalies, premature birth, low birth weight, leukemia in children, and Alzheimer's disease
Styrene	Depression, concentration issues, tiredness, muscle weakness, nausea, throat irritation, eye irritation respiratory and gastrointestinal effects, mucous membrane and eye irritation, headache, fatigue, and weakness	Depression, CNS dysfunction-reaction time, memory, visuomotor speed and accuracy, and intellectual function, hearing loss, peripheral neuropathy, spontaneous abortions, carcinogenesis, DNA strand breaks, sister-chromatid exchanges, and alterations in the defense mechanisms such as the antioxidant system and DNA repair process
Acetone	Eye, nose, and throat irritation, headache, dizziness, dermatitis	CNS depression, unsteadiness, confusion, and unconsciousness

Formaldehyde - Agency for Toxic Substances and Disease Registry [ATSDR], (2011), Aydogen & Montoya, (2011), EPA, (2013a), and Xu, Wang, and Hou (2011).

Styrene - EPA (2013b), Roder-Stonlinski, Fischader, Oostingh, Feltens, Kohse, Bergen, Morbt, and Eder. (2008), Wongvijitsuk, Navasumrit, Vattanasit, Parnlob, and Ruchirawat (2011).

Acetone - Arts, Mojet, Gemert, Emmen, Lammers, Marquart, Woutersen, and Feron (2002), and Centers for Disease Control and Prevention (CDC) (2010).

Plant Information

An assortment of plant species were used for this study to determine if improvement of indoor air quality occurred. In a past study completed by Wolverton and Wolverton (1996), the researchers investigated other ways to improve indoor air quality. Before the researchers arrived at the conclusion of using interior plants, they first investigated the recommendations put forth by the American Society of Heating, Refrigeration, and Air Conditioning Engineers to increase the minimal supply of outdoor air per minute per person. The results of this study concluded that even with increasing the ventilation rates in these buildings, the issue of sick building syndrome was still not completely eliminated. This information led the researchers to attempt other ways to reduce airborne microbes. According to Wolverton and Wolverton (1996), "since planet Earth's clean air originates from living, green plants, the concept of designing houseplants inside tightly sealed buildings to purify and revitalize indoor air has a scientific basis" (p. 99). Furthermore, the researchers believed that this concept would possibly require "treating each building as a miniature earth with its own built-in living air purification system" (p. 99). This study modeled the research of Wolverton and Wolverton (1996) by using four enclosed offices in the two buildings and was therefore treated separately from the rest of the building.

In this one-group pretest-posttest study, the three plant species were placed in each office and not removed for six weeks. Therefore, the plants remained in the offices regardless of internal or external temperature and during entire 24-hour cycles for a total time of six weeks. In a study conducted by Xu, Wang, and Hou (2011), the researchers discovered through their experiment that the plant soil removed greater amounts of formaldehyde in the daytime when compared to the nighttime. They also discovered that the golden pothos plant removed formaldehyde when stimulated by slightly increasing the light intensity. When the researchers determined the formaldehyde removal tendencies of the plant shoots, they again found that more formaldehyde was removed in the daytime when compared to the nighttime. They discovered the same result when testing the soil. Kim et al. (2008) reported that “formaldehyde was assimilated about five times faster in the light than in the dark” (p. 521).

In a study conducted by Sawada and Oyabu (2007), the researchers found that “purification capability was higher as the light intensity became higher” as well as concluding that “the pothos in the pot-soil had the highest capability in the experimental range” (p. 599). Ultimately, it can be concluded that the majority of plants, despite the plant part examined, were more efficient in the air purification process in the daytime rather than the nighttime.

In analyzing the research articles related to purification characteristics of various forms of plants, the *Epipremnum aureum* (Golden Pothos) was chosen for this research due to the purification capabilities reported by Sawada and Oyabu (2008). The researchers reported, “the purification capability of the pothos growing in pot-soil, for formaldehyde, toluene, and xylene was the highest” (p. 601), however, only the formaldehyde removal capabilities of the pothos was examined from this research. The *Dieffenbachia* (Dumb Cane), *Epipremnum aureum* (Golden Pothos), and *Ficus elastica* (Rubber Fig) were all chosen for this research due to the size, availability, and pricing. The *Dieffenbachia* (Dumb Cane) plant species, however, needs to be chosen for research with caution. According to Cumpston, Vogel, Leikin, and Erickson (2003), “oral ingestion of any part of the Dieffenbachia can cause immediate pain, edema, salivation, ulceration, vomiting, diarrhea, and dysphagia. It has been reported that for toxicity to occur the integrity of the leaf or the stem must be broken” (p. 395). Accordingly, it is vital that the *Dieffenbachia* (Dumb Cane) plant species not be used when children or pets are in the general vicinity due to the possibility of placing plant parts in their mouths, either purposefully or accidentally.

There is also concern about other negative connotations surrounding the introduction of indoor plants into enclosed spaces. In the study performed by Wolverton and Wolverton (1996), the researchers mentioned, "concern has been expressed that if large numbers of interior plants are placed in tightly sealed, energy-efficient buildings, excessive increases in relative humidity levels will occur because of transpiration. The major concern is that increased humidity levels will cause excessive growth of mold spores and other airborne microbes, and thus create a greater indoor air pollution problem that currently exists" (p. 100). Conversely, the researchers also reported that by increasing the indoor humidity levels, people who suffer from asthma or allergy attacks may experience fewer problems as the plants raise the indoor humidity level. In regards to the concerns over increasing humidity levels and mold spores, the researchers determined, "houseplants may be used instead of humidifiers for adding moisture to offices and homes. Plants transpire mineral-free moisture that appears to contain substances that suppress growth of airborne microbes. These data suggest that if increased humidity levels inside energy-efficient buildings are from houseplants, airborne microbial levels may be less than from humidity increases by other means" (p. 102). In concurrence with the researchers in this study, a conclusion can be formed that although indoor plants could potentially increase the levels of humidity indoors, the humidity is to a lesser extent than by other methods, and issues regarding asthma and other allergic issues could be resolved further.

How Can Plants Clean the Air?

"In some metropolitan areas, indoor air has been found to be up to 100 times more polluted than outdoor air posing health effects and negative economical consequences"

(Aydogan & Montoya, 2011 p. 2675). With the knowledge that formaldehyde, acetone, and styrene have the potential to cause serious health effects, it is crucial to find ways of reducing these chemicals and keeping the people who are exposed to them safe. “Plants are known to absorb and metabolize gaseous formaldehyde” (Kim et al. 2008). According to Xu, Wang, and Hou (2011), “various plants can remove formaldehyde from indoor air by means of the uptake and metabolism. One part of absorbed formaldehyde is oxidated into carbon dioxide in the Calvin Cycle while the other is incorporated into the organism including organic acids, amino acids, lipids, and cell-wall components” (p. 314). Wolverton and `Wolverton (1996) stated, “research studies have shown that houseplants absorb, metabolize, or translocate air polluting organic chemicals to microbes growing on and around plant roots where they are biodegraded” (p. 100). There is much evidence in these studies that plants will decrease the amount of VOCs through various processes within the plants, thus, decreasing the harmful effects of these VOCs in the human body.

Methods

The research question that guided this study was: Does the addition of indoor plants reduce the levels of VOCs in office settings? In this one-group pretest-posttest study, materials consisted of the indoor plants species, *Dieffenbachia* (Dumb Cane), *Epipremnum aureum (*Golden Pothos), and *Ficus elastica* (Rubber Fig) and vapor monitors for formaldehyde, styrene, and acetone. The monitors were purchased from Advanced Chemical Sensors Inc. in Boca Raton, Florida. One Organic Full Scan Vapor Monitor, which measures over 100 VOCs, was placed in each office for 120 hours and tested the initial levels of styrene and acetone. All VOCs that can be detected by this monitor are listed in the Appendix. One Formaldehyde Vapor Monitor was placed in each office for 48 hours and tested the initial levels of formaldehyde. The levels of VOCs were measured using these vapor monitors in four offices on a college campus in the Southeastern part of the United States; two offices in a newer building built in 2008 and two offices in an older building built in 1976. The levels of VOCs in the four offices were tested initially before any plants were added to the offices. One Organic Full Scan Vapor Monitor and one Formaldehyde Vapor Monitor was placed approximately four feet from the ceiling on top of a cabinet in each office and sent to the lab for analysis. The Organic Full Scan Vapor Monitor was left in place for 120 hours, while the Formaldehyde Vapor Monitor was left in place for 48 hours. After the initial tests, the three plant species were added to each office and remained for six weeks. Post plant VOC levels were tested at the four week mark and then repeated at the six week mark to determine if any change in the VOC levels had occurred. At the four week interval, one Organic Full Scan Vapor Monitor and One Formaldehyde Vapor Monitor was placed again approximately four feet from the ceiling on top of a cabinet in each office. The Organic Full Scan Vapor Monitor was left in place for 120 hours, while the Formaldehyde Vapor Monitor was left in place for 48 hours, as indicated previously. This method was repeated again after the plants remained for six weeks. After the initial VOC levels were obtained and the four and six week post plant VOC levels were obtained, all results were placed in a graph to make it easier to compare the pre-plant VOC levels and the post-plant VOC levels.

Results

The VOC levels reported from Advanced Chemical Sensors Inc. were communicated by using the parts per billion (ppb) unit. The formaldehyde levels reported from Advanced Chemical Sensors Inc. were communicated using the parts per million (ppm) unit. The initial VOC levels were higher in the older building constructed in 1976 when compared to the initial

VOC levels reported from the newer building constructed in 2008. Numerous VOCs were detected by the Advanced Chemical Sensors Inc. monitors. For this research, acetone, styrene, and formaldehyde were considered specifically to determine if reduction had occurred after indoor plants were added to the four offices.

In the first office tested in the newer building, the initial results reported were as follows: acetone - 1.60 ppb and formaldehyde - 0.003 ppm. No styrene was detected at any time. The four week post-plant results for office one were reported as follows: acetone - 1.22 ppb and formaldehyde - 0.007 ppm. The six week post-plant results for office one were reported as follows: acetone - 2.41 ppb and formaldehyde - 0.002 ppm**.** In office one, acetone decreased by the fourth week, but increased by the sixth week. Formaldehyde increased by the fourth week, but decreased again by the sixth week post plant test. See Figures 1 and 2 for a graphic display of these findings.

Office two located in the newer building yielded the following results for initial testing: acetone - 3.05 ppb and formaldehyde - 0.003 ppm. No styrene was detected at any time. After the plants were added and remained in place for four weeks, office two yielded the following results: acetone - 1.79 ppb and formaldehyde - 0.007 ppm. After the plants remained in place for six weeks, office two yielded the following results: acetone - 2.81 ppb and formaldehyde - 0.003 ppm. In office two, acetone decreased by the fourth week, but increased by the sixth week. Formaldehyde increased by the fourth week, but decreased by the sixth week. See Figures 1 and 2 for a graphic display of these findings.

Office three located in the older building yielded the following results for initial testing: acetone - 2.37 ppb and formaldehyde - 0.005 ppm. No styrene was detected at any time. After the plants were added and remained in place for four weeks, office three yielded the following results acetone - 2.43 ppb and formaldehyde - 0.005 ppm. After the plants remained in place for six weeks, office three yielded the following results: acetone -1.98 ppb and formaldehyde - 0.003 ppm. In office three, acetone increased by the fourth week, but decreased by the sixth week. Formaldehyde remained the same by the fourth week, but decreased by the sixth week. See Figures 1 and 2 for a graphic display of these findings.

Office four located in the older building yielded the following results for initial testing: acetone - 1.89 ppb and formaldehyde - 0.007 ppm. No styrene was detected at any time. After the plants were added and remained in place for four weeks, office four yielded the following results: acetone - 6.63 ppb. After the plants were added and remained in place for six weeks, office four yielded the following results: acetone -1.97 ppb and formaldehyde - 0.003 ppm. In office four, acetone increased by the fourth week, but decreased by the sixth week. Formaldehyde was not detected by the fourth week, but was detected by the sixth week. See Figures 1 and 2 for a graphic display of these findings.

Figure 1, Acetone Levels

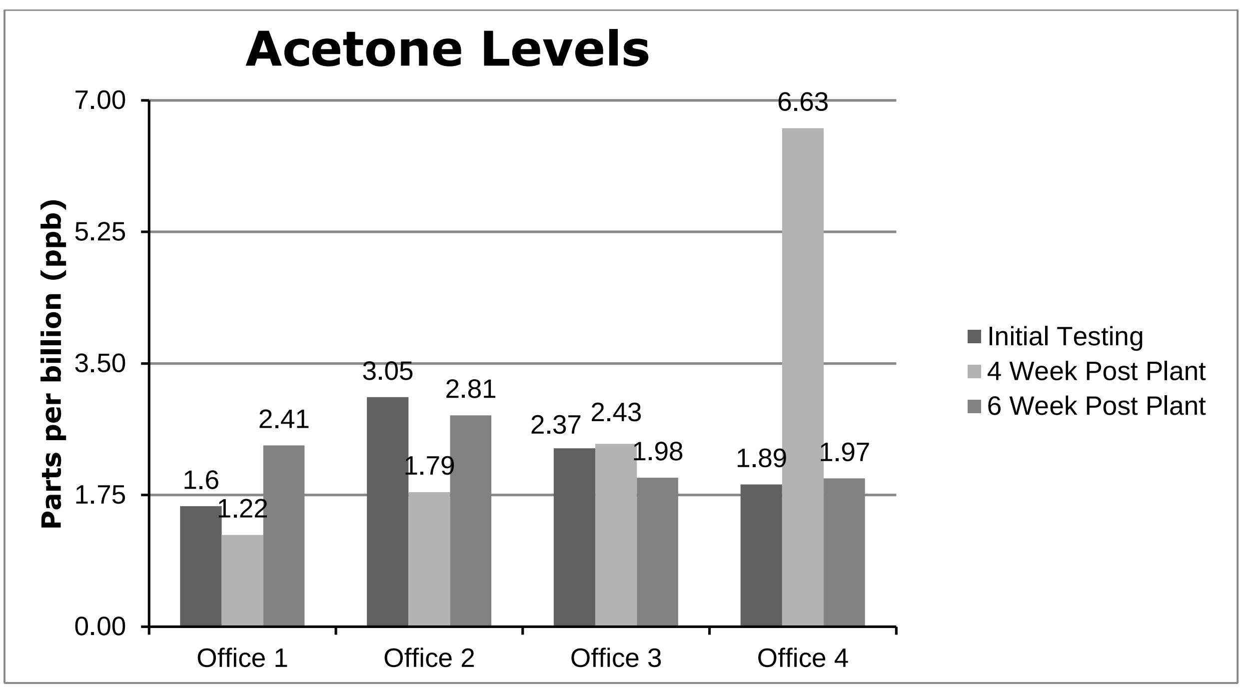
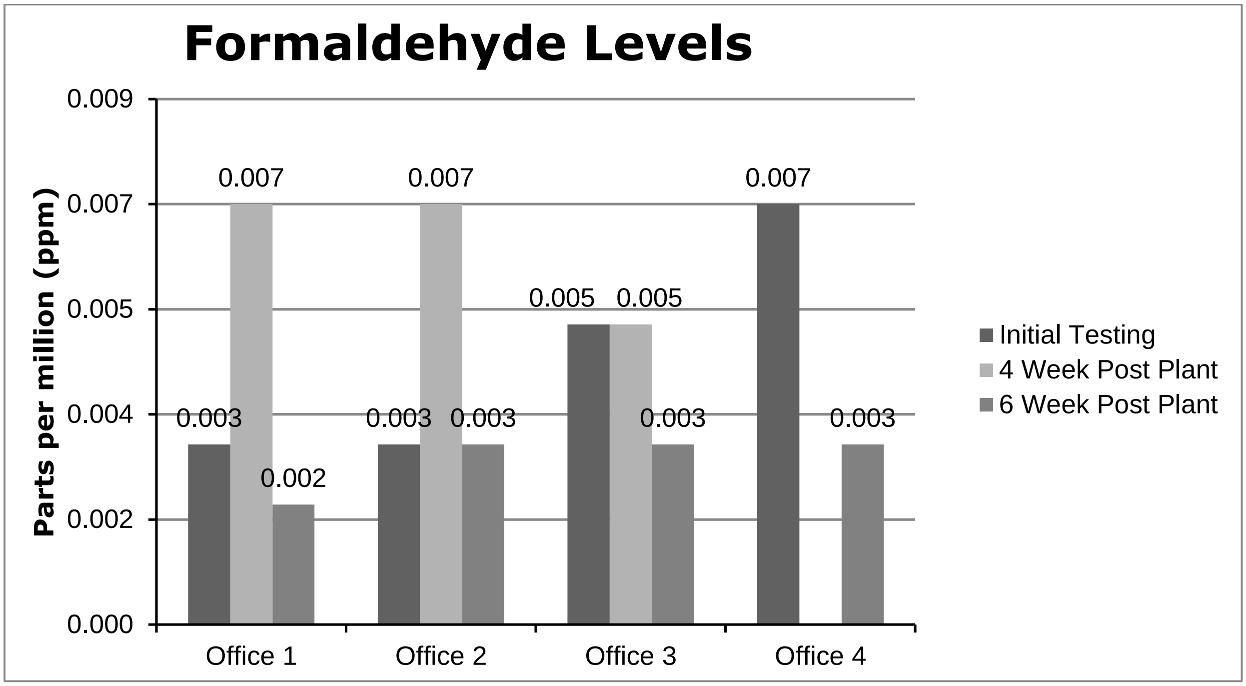


Figure 2, Formaldehyde Levels



Limitations

Numerous limitations existed throughout this study. After the initial testing for the VOC levels, the plants were added to the offices of the newer building during the cooler months of the year. The *Dieffenbachia* (Dumb Cane) became too cold during transportation from store, to car, to office, and needed to by nurtured back to health. In the meantime, an additional *Epipremnum aureum* (Golden Pothos) plant was added to each office to replace the *Dieffenbachia* (Dumb Cane). This plant was chosen as a replacement due to its pricing, availability, and durability during the winter months. Also, no control room was used in either the newer building or the older building. A control room would have allowed the researcher to measure VOCs in rooms without plants in order to make direct comparisons about the effect of plants. Moreover, neither the indoor temperatures nor the outdoor temperatures were recorded on the three testing days.

There has been some suggestion that increasing temperatures and sunlight exposure could possibly increase the amount of VOC levels. According to Kagi, Fujii, Tamura, and Namiki (2009), secondary emissions of formaldehyde increased with ultraviolet (UV) radiation exposure. In future studies, it would be wise to test the levels of internal and external temperatures to determine if there is a positive correlation between the increasing surrounding temperature and the increasing VOC levels. Furthermore, during the testing of the older building constructed in 1976, a new building was being constructed +-50 feet away from the offices tested for this study. There is a high probability that VOC levels increased in the older building due to the outdoor air pollution occurring +-50 feet away, that potentially turned into indoor air pollution.

Discussion

As previously stated, VOC levels have the possibility of increasing when introduced to higher temperatures or UV radiation. In the newer building constructed in 2008, acetone did decrease after allowing the plants to remain for four weeks. However, the six weeks post plant results indicated that the acetone level increased, potentially due to the increasing outdoor temperatures and sunlight. Acetone levels in the second office yielded similar results by decreasing by the fourth week post plant, but increasing by the sixth week post plant, possibly due to an increase in outdoor temperature as well as sunlight exposure. Formaldehyde levels in the first office located in the newer building increased by the fourth week possibly due to the increasing outdoor temperatures as well as increased sunlight exposure. However, the formaldehyde level decreased again by the sixth week. This result allows for questioning of the possible correlation between increased temperature, increased sunlight exposure, and increased VOC levels. It is feasible that the plants were efficient in removing VOCs from the newer offices after remaining in place for four weeks. To combat the increasing temperature and sunlight exposure, more plants could be added to the offices or shading could be provided during the sunniest or warmest portions of the day.

As mentioned earlier, it is a possibility that construction in close proximity to the offices tested for this research contributed to the increase in VOC levels. In the older building constructed in 1976, a new building was being constructed +-50 feet away from the offices tested. Acetone increased by the fourth week in both office three and office four possibly due to construction as well as increasing temperatures and sunlight exposure, however, the acetone decreased in both offices by the sixth week. Conversely, formaldehyde remained the same by the fourth week, but decreased by the sixth week. Similar results occurred regarding formaldehyde in office four with a decrease by the sixth week. When evaluating the results in the older building, it is feasible to determine that the indoor plants were a contribution to the overall decrease in formaldehyde and acetone levels in both office three and four.

Implications for nursing practice

Nurses are a vital component used in the healthcare profession and many spend quality and lengthy amounts of time with patients depending on patient needs. Education is an immense element involved in the nursing role and this research could potentially open doors to new ways of treating patients by using a holistic technique and preventative measures. We are now aware that as the construction of new buildings is occurring and that people spend the majority of their time predominantly in indoor environments, likely newly constructed buildings with higher VOC levels, they are becoming exposed to harmful chemicals at an alarming rate. As healthcare providers, nurses can educate people about what these harmful chemicals are, where they come from, how people are exposed to them, and what exposure to these chemicals can produce.

Nurses can also introduce efficient and cost effective methods to decrease these chemicals in the places where people spend the most time. It is also essential that nurses communicate information regarding which plant species are cost effective, which ones are efficient and easy to care for like the *Epipremnum aureum (*Golden Pothos), and which ones could potentially be dangerous if ingested like the *Dieffenbachia* (Dumb Cane).

Additionally, the health hazards involving VOCs are so vast, ranging from slight annoyances to life-threatening illnesses, education could be monumental in preventing these health effects. It was Florence Nightingale who stated, “it is the role of the nurse to alter the environment in such a way as to obey the natural laws, thereby providing the environment in which perfection might be achieved” (Sclanders, 2010, p. 83). Sclanders also included in the article the connotation made by Nightingale involving environmental alterations. She stated, “through environmental alteration, one is able to put the patient in the best possible condition for nature to act, thereby facilitating the laws of nature” (Sclanders, 2010, p. 83). These implications acclaimed by Nightingale allow nurses in this society to pay attention to every aspect of patient care, for each and every component is significant in the accolade of patient care.

Implications for future research

Future research is important to determine if VOCs are reduced by testing specific types of plants. Also, control rooms that are not altered by adding plants are needed to determine VOC levels, both initially and during testing times of the experimental rooms. Temperature, both internally and externally, should be recorded as well as humidity levels, both internally and externally. It would also be insightful to test a room that can be manipulated with window shading from sunlight and to choose rooms that are not in close proximity to construction. These future studies could have great implications for the health of individuals working and living within these structures.

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Appendix

VOCs detected from the Advanced Chemical Sensors Inc. Full Scan Monitor

Acetone	Ethyl Acetate
Acetonitrile	Ethyl Acrylate
Acrylonitrile	Ethyl Alcohol
Ally Chloride	Ethyl Benzene (Ethyl Benzol)
Alpha-Pinene	Ethyl Ether
1-Butyl Alcohol	Ethyl Methacrylate
2- butanone (MEK)	1-Hexanol
2-Butyl Alcohol	1-Hexyne
Benzene	2-Heptanone
Benzene, 1-Chloro-4(Trifluoromethyl)	Heptane
Benzyl Alcohol	Hexane
Benzyl Chloride	Hexone (MIBK)
Butane	Isobutyl Acetate
1,3-Butadiene	Isobutane
Butyl Acetate	Isooctane
Butyl Cellosolve	Isopropyl Alcohol
Butyl Ether	1-Methyoxy-2propanol
Carbon Tetrachloride	2-Mercaptoethanol
Cellosolve	5-Methyl-2-Hexanone (MIAK)
Chlorobenzene	2-Methylbutane
Chloroform	MEK Oxime
Cyclohexane	Methyl Acetate
Cyclohexanol	Methyl Acrylate
Cyclohexanone	Methylbromide
Cyclohexene	Methyl Chloroform
Diacetone Alcohol	Methyl Methacrylate
1,2 Dichlorobenzene	Methyl Styrene

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
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

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
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

2,3-Dimethylpentane	Bourgenol
3,3-Dimethylpentane	Anethole
	Camphene
Methylcyclohexane	Methylparacresol
Methylcyclopentane	Furfuryl Alcohol
	Estragole
1,2-Dimethylcyclopentane	2-Methyl-1-Butyl Acetate
1,2-Dimethylcyclohexane	Diacetyl
	2-Hexenal
2-Methylheptane	Acetylpropionyl
	Isobutyl Isobutyrate
Dimethoxymethane	Urethane
2-Methyl-1-Propanol	Iosprene
2-Methyl-2-Propane	Camphor
Methyl t-Butyl Ether	1,2-Dichloroethylene
1-Butanethiol	Dimethyl Sulfide
2-Butanethiol	5-Methyl Sulfide
Butyl Disulfide	o-Cymene
Carbonyl Sulfide	m-cymene
Chloromethane	t-Butyl Acetate