MEASUREMENT AND ANALYSIS OF INDOOR AIR POLLUTANTS IN A ROOM SPRAYED WITH A LOCALLY MANUFACTURED AIRFRESHENER

Perera S. A. S.1, Jayasinghe C.2 ,Gunaratne W. D. S. P.3, Gunatilake M. M. D. V.3, Madushanka H. K. R.3, Perera T.M.4 1Professor,
Department of Chemical Engineering, University of Moratuwa, Sri Lanka
2Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka
3Final year undergraduates, Department of Civil Engineering, University of Moratuwa, Sri Lanka
4Postgraduate student, Department of Civil Engineering, University of Moratuwa, Sri Lanka

Abstract

In the modern world, since, people like to live, work and travel in, aesthetically pleasing, comfortable environments with pleasant odour, they tend to use, decorative interiors, air conditioners and air fresheners, whereas, during good old days, natural alternatives, such as, natural ventilation, natural fragrances and natural interiors were used to make living comfortable. Today, in most of the indoor environments, air fresheners are sprayed, to give a pleasant odour. This is practiced in most commercial buildings, factories, houses, as well as, cars and other modes of transport. However, many studies conducted by researchers, internationally, have. revealed that many chemicals are used in the manufacture of air fresheners, some of which, might have adverse impacts on human health. The main objective of this research project was to measure and analyse concentrations of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOC) and Particulate Matter less than 2.5 microns ($PM_{2.5}$), due to the spray of air freshener into an air conditioned office room, with no external air circulation. To make the research relevant to Sri Lanka, a locally manufactured, popular brand of air freshener packed in a non pressurised finger operated spray bottle, was used to spray air freshener into the room. The results have revealed that, the indoor air TVOC levels can significantly rise beyond permissible limits, in an air conditioned room, with no external air circulation.

Key words: Indoor Air Quality (IAQ), Air freshener, Carbon Monoxide (CO), Carbon Dioxide (CO_2), Total Volatile Organic Compounds (TVOC), Particulate Matter (PM)

1. Introduction

Many people, such as, students, office workers, factory workers and many others, spend more than 90 % of their life within indoor environments, while they are living, working and travelling.

In the modern world, since, people like to live, work and travel in, aesthetically pleasing, comfortable environments with pleasant odour, they tend to use, decorative interiors, air conditioners and air fresheners, whereas, during good old days, natural alternatives, such as, natural ventilation, natural fragrances and natural interiors were used to make living comfortable. Today, in most of the indoor environments, air fresheners are sprayed, to give a pleasant odour. This is practiced in most commercial buildings, factories, houses, as well as, cars and other modes of transport. However, many studies conducted by researchers, internationally, have revealed that many chemicals are used in the manufacture of air fresheners, some of which, might have adverse impacts on human health.

Manufacturers are producing different types of air fresheners that could easily be adapted to different conditions. The broad range of air fresheners (AF) types include, pressurised and non pressurised spray cans, continuous release or timer operated spray systems, solids, gels, fragrant candles, incense sticks and potpourri. [1]

Although AFs are commonly used, it has been found that in air freshened environments, some people who are sensitive and allergic to some of the chemicals in AFs, have experienced discomforts, such as, headaches, eye irritation and respiratory problems. Thus, the effect of air fresheners on indoor environment quality has been a timely and a useful research study.

In order to understand the indoor air pollution it is very essential to identify causative agents and the sources of them. Sulphur Dioxide (SO_2),Nitrogen Dioxide (NO_2),Carbon Monoxide (CO) ,Volatile Organic Compounds (VOC),Carbon Dioxide (CO_2), Particulate Matter (PM) can be identified as common types of causative agents. Based on the chemicals present, the impact on indoor comfort and occupant health can vary. The variations of these are also dependent on the different ventilation types, such as, air conditioned with or without external fresh air circulation and natural ventilation through doors, windows and fans.

2. Objectives

The main objective of this research project was to measure and analyse concentrations of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Total Volatile Organic Compounds (TVOC) and Particulate Matter less than 2.5 microns ($PM_{2.5}$), due to the spray of air freshener into an air conditioned office room, with no external air circulation. To make the research relevant to Sri Lanka, a locally manufactured, popular brand of air freshener packed in a non pressurised finger operated spray bottle, was used to spray air freshener into the room.

Determination of,

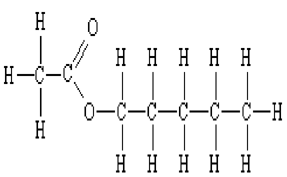
1. Concentrations of causative agents due to air fresheners and the dispersion.
2. Effect of ventilation type on dispersion.

3. Components in liquid air fresheners

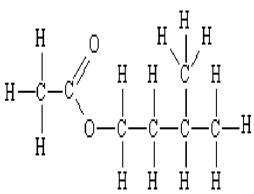
In general, a liquid air freshener consists of a fragrance dissolved in volatile solvents, which dilutes the fragrance and disperses it in air. Fragrances are very expensive and volatile solvents too are expensive. Hence, to reduce the cost, a small amount of fragrance is dissolved in a solvent mixture, which contains more than 60% water. Fragrances are produced from esters (which are artificial) or essentials oils (which are natural) or their combinations. Most esters are artificially produced while essential oils are extracted from flowers, leaves and other components of plants. Since, there is only a small concentration of essential oil in plant components, the extraction process is extremely expensive, due to which prices of essential oils are extremely high compared to artificially produced esters. Alcohols are cheaper than fragrances. Pthalates are used to facilitate mixing unifining the mixture.

Esters

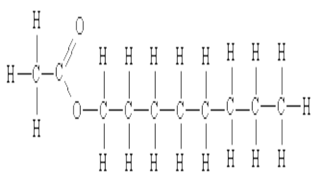
Some esters commonly used in fragrances are given below [3].



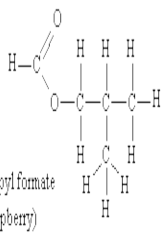
pentyl acetate (pears)



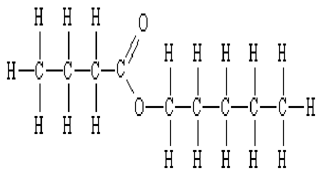
3-methylbutyl acetate (bananas)



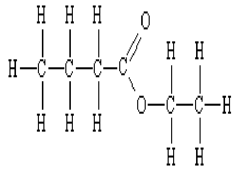
octyl acetate (oranges)



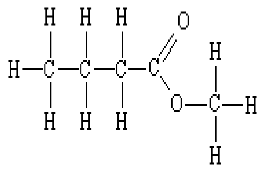
methylpropyl formate (raspberry)



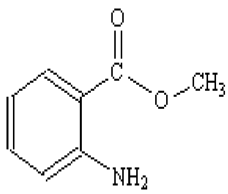
pentyl butyrate (apricot, strawberry)



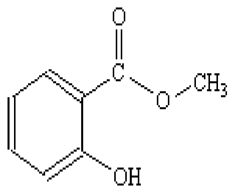
ethyl butyrate (pineapple)



methyl butyrate (apple)



methyl anthranilate (grape)



methyl salicylate (wintergreen)

Essential Oils

Some Essential Oils Used in Fragrances are given below [4]. They contain many natural esters and other chemicals that give their characteristic odours. Toxicities of most of these essential oils and esters are fairly low. However there are other chemicals used in air fresheners that could have higher toxicity levels.

Jojoba Oil, Grapeseed Oil, Bergamot Essential Oil, Cedarwood Essential Oil, Frankincense Essential Oil, Grapefruit Essential Oil, Jasmine Absolute Essential Oil, Lavender Essential Oil, Orange Essential Oil, Palmarosa Essential Oil, Patchouli Essential Oil, Rose Absolute Essential Oil, Rose Geranium Essential Oil, Vanilla Absolute Essential Oil, Ylang Ylang Essential Oil

Alcohols

Commonly used alcohols are ethyl alcohol, propyl alcohol and isopropyl alcohol (IPA) and butyl alcohol. Isopropyl alcohol is the most commonly used, since it is less expensive.

Pthalates

Pthalates are used as emulsifiers to mix the fragrance, alcohol and water. However, some phthalates listed below, which are known to be carcinogens, have been found in AFs, as per studies conducted by researchers.[8]

- Di-thly Phthalate (DEP)
- Di-n-butyl Phthalate (DBP)
- Di-isobutyl Phthalate (DIBP)
- Di-methyl Phthalate (DMP)
- Di-isohexyl Phthalate (DIHP)

If only alcohols are used in AFs , due to their high volatilities, when the AF is sprayed, odour remains only for a short time. Since phthalates are less volatile, when they are mixed with fragrances, alcohols and water the pleasant odour lasts for a longer time.

4. Methodology

4.1.Test Chamber

The study took place in an office room located at the structural testing laboratory of the Department of Civil Engineering, University of Moratuwa. This room consisted of two compartments, connected to each other by a sliding window of the dimensions, 0.7m x 1.15m. Each compartment has its own door as indicated in Figure 1. (D_1- 0.85m x 2.05m, D_2- 0.9m x 2. 05m)

The room mainly contained wooden furniture which included desks and chairs. In addition, it had a steel cupboard, few plastic chairs and one fabric chair. Therefore the effect of fabrics, which absorbs the contaminants and releases with time, has not become a major issue in this study.

Both compartments of this room were ventilated by one window type air conditioner, which was located as indicated in the Figure 1. In order to assess the effect of the air freshener spray in isolation, on the IAQ of the room, occupant density of the room has been kept as zero throughout the experiment (other than the instance of spraying the air freshener)

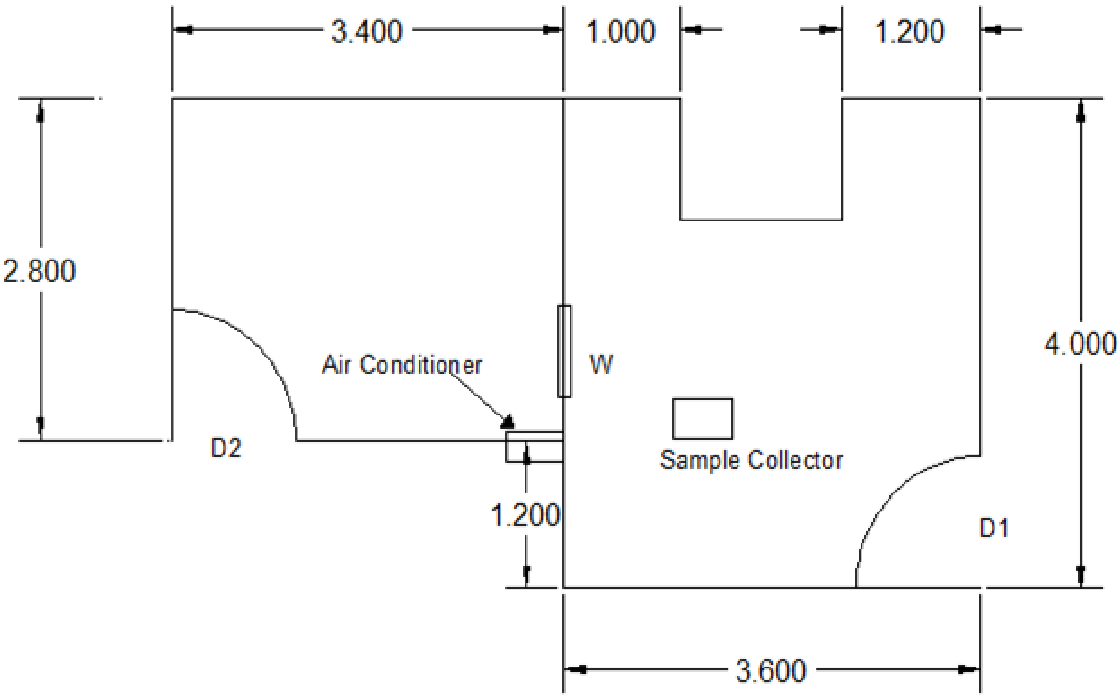


Figure 1: Plan View of the Test Chamber (Dimensions are in *meters*)

4.2.Pollutants under consideration and the equipment used

The study was to measure the variations occurred in the concentrations of indoor air pollutants such as Carbon Monoxide (CO), Volatile Organic Compounds (VOC), Carbon Dioxide (CO_2), Particulate Matter ($PM_{2.5}$) under the influence of air freshener spray. Apart from those, the variation of room temperature and Relative Humidity were also recorded.

The pieces of equipment used in this study were Indoor Air Quality Monitor and Haz-Dust Particulate Air Monitoring Equipment.

Indoor Air Quality Monitor (IQM60 Environmental Monitor V5.0) was used to measure the concentrations of CO, Total VOC, CO_2, Room temperature and Relative humidity. Haz-Dust Particulate Air Monitoring Equipment was used to measure the concentrations of $PM_{2.5}$ throughout the test.

4.3.Experimental programme

Instruments were placed at a height of 0.9m from the ground to simulate the working height of an occupant seated on a chair. Both the instruments were plugged in for warming up for one hour and the measurements were taken for half an hour to obtain the regular IAQ of the room. Then 40ml of air freshener was sprayed inside the room, making sure homogenous distribution and above mentioned measurements were taken until they disperse to attain their regular levels. Test was conducted under AC and free running conditions to observe the effect of ventilation on dispersion of air fresheners. Test results for each ventilation condition were averaged from the measurements taken by creating the same condition for several days.

5. Results and Discussion

When the air freshener was sprayed, concentrations of different causative agents showed different variation patterns. A significant variation could be witnessed under different ventilation conditions: air conditioned environment and free running environment. The dispersion was observed faster under the free running condition.

After analysing the recorded data, a Toxicity Index was developed for each and every causative agent under both the ventilation conditions.

$$\boldsymbol{Toxicity\ Index} = \frac{Concentration\ of\ the\ causative\ agent}{Permissible\ concentration}$$

Permissible concentrations for each causative agent are listed in *Table 1*.

Table 1: Permissible Concentrations of Parameters

Parameters measured	Permissible value
CO	9 ppm [a] (24 hr)
TVOC	0.75 ppm [b] (24 hr)
CO_2	1000 ppm [a] (24 hr)
$PM_{2.5}$	0.025 mg/m^3 [c] (24 hr)

[a] - ASHRAE Standards [5]

[b] - OSHA Standards [6]

[c] - WHO Guidelines [7]

5.1. Carbon Monoxide (CO)

When the air freshener was sprayed, CO concentration within the room showed a rapid increase from its initial concentration (0 ppm) and gradually got dispersed with time. Although, it showed a rapid increase of concentrations in both ventilation conditions, peak values recorded were different. The peak value in the AC environment was more than twice, that of the free running condition. CO concentration inside the room, has taken more time to get dispersed in the AC environment. It was 4.5 times higher than that of the free running condition.

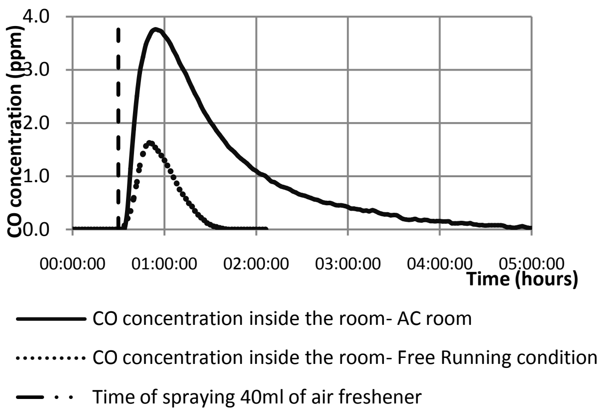


Figure 2: CO concentration vs. Time

Although the CO concentration showed a rapid increase with the air freshener spray, it did not exceed the permissible value for 24hour exposure. (*Table 1*) This is clearly illustrated in the graph which contains the Toxicity Index of CO. Highest toxicity index it obtained was about 0.4 (in the AC environment), which was twice the highest value obtained in the free running environment.

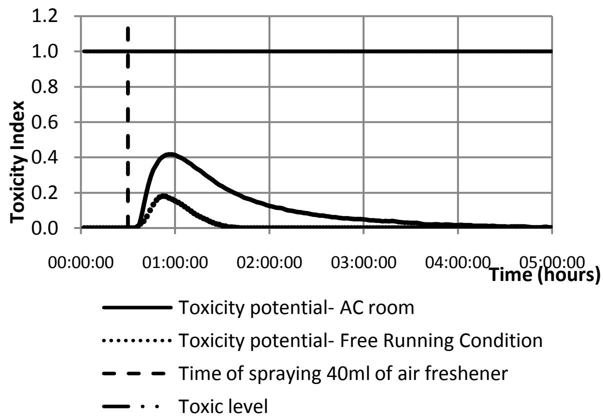


Figure 3: Toxicity Index of CO vs. Time

5.2. Total Volatile Organic Compound (TVOC)

At the instance air freshener was sprayed, Total VOC concentration within the room drastically increased from its initial concentration (0 ppm) and showed a gradual dispersion with time. Although, the variation patterns in both the ventilation conditions were the same, peak TVOC concentration under AC environment was two times that obtained under the free running condition. The dispersion time for AC environment was higher, as it was noticed with CO. The AC to free running ratio for dispersion time was observed to be 6 for TVOC. The variation of TVOC concentration is shown in *Figure 4*.

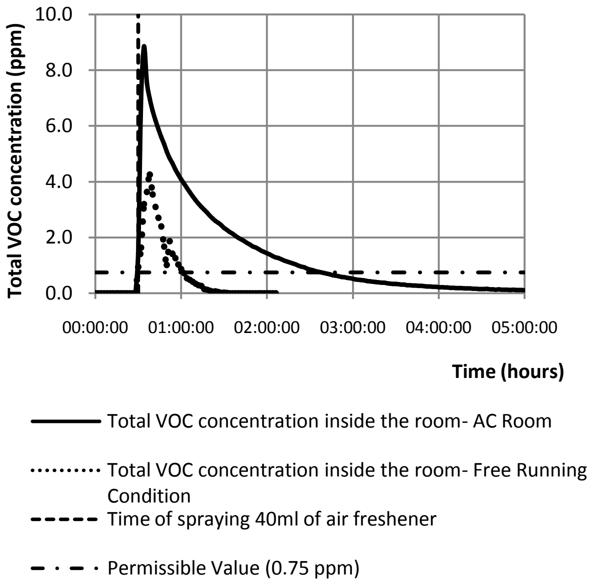


Figure 4: TVOC concentration vs. Time

As shown in the graph (Figure 4) the TVOC concentration was exceeding the permissible value for 24 hour exposure (*Table 1*), continuously for almost 2 hours in the AC environment. But in the free running environment, it lasted only for 30 minutes. The highest concentration of TVOC observed during the experiment was well above the permissible value. How toxic the indoor air could be due to the air freshener spray, is highly noticeable in the graph shown in Figure 5, of TVOC's Toxicity Index.

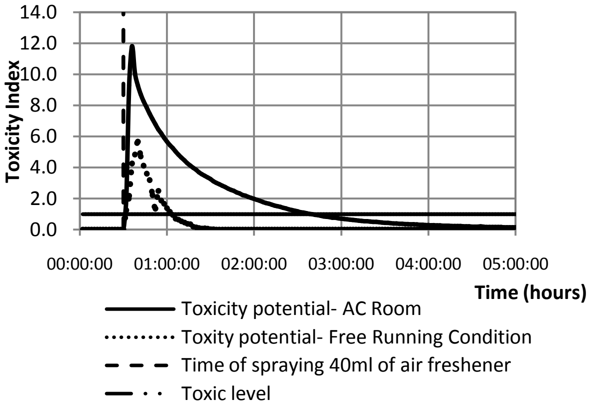


Figure 5: Toxicity Index of TVOC vs. Time

5.3. Carbon Dioxide (CO_2)

Occupant density is a major concern with respect to the CO_2 concentration within a room. As mentioned above, since occupant density was kept zero in this set-up, the effect from the air freshener spray for the CO_2 concentration could be isolated. Thus the slight variation occurred in the CO_2 concentration (with respect to the ambient CO_2 concentration within the room) could be identified.

At the instance of the spray, the CO_2 level rises in both the ventilation conditions. But it only lasted for nearly 30 minutes till it reached its initial value.

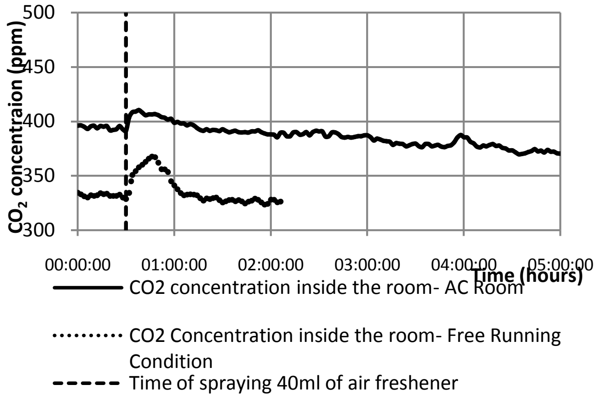


Figure 6: CO_2 concentration vs. Time

Although the change in CO_2 concentration with the air freshener spray is quite high under the free running condition whereas, the CO_2 level has not even reached the initial CO_2 level of the air conditioned environment. Hence the Toxicity Index of CO_2 is far below the Toxic level.

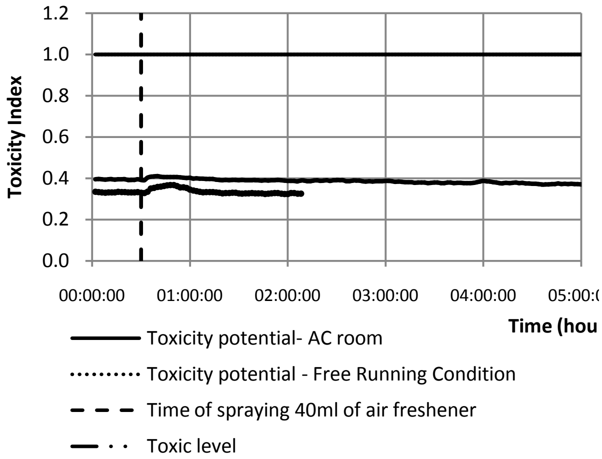
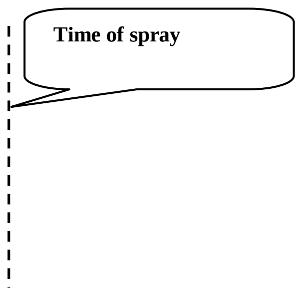


Figure 7: Toxicity Index of CO_2 vs. Time

5.4. Particulate Matter ($PM_{2.5}$)

When the air freshener was sprayed, the $PM_{2.5}$ concentration has increased. It was observed that the increase in $PM_{2.5}$ concentration under air conditioned environment was higher than that of free running condition. (*Figures 8 and 9*)



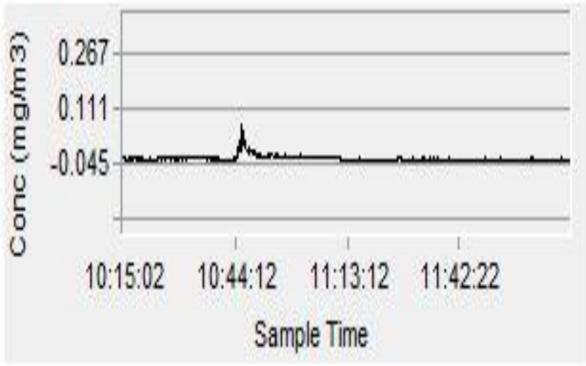


Figure 8: $PM_{2.5}$ concentration vs. Time (AC environment)

5.5. Temperature and Relative Humidity

No significant change could be witnessed in the temperature, inside the room due to the air freshener spray under both ventilation conditions considered. However, there was a slight increase in the relative humidity at the instance at which the air freshener was sprayed. This increase was higher in the air conditioned environment.

A summary of the results is shown in *Table 2.*

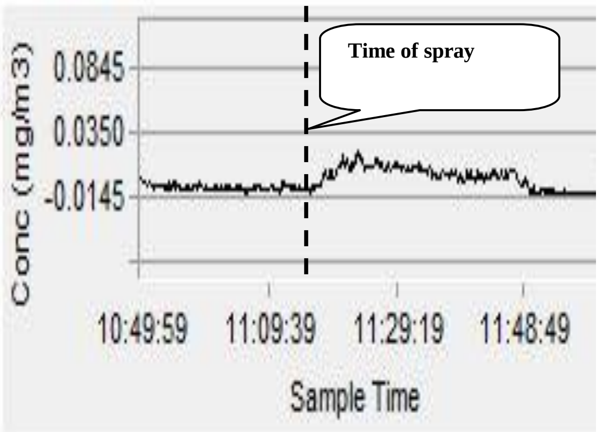


Figure 9: $PM_{2.5}$ concentration vs. Time (Free running environment)

Table 2: Summary of Results

Ventilation	AC environment	Free running	AC / Free Running

condition			environment		Ratio	
Parameter	**Peak value**	**Dispersion time**	**Peak value**	**Dispersion time**	**Peak value**	**Dispersion time**
CO	3.76	4.5hrs	1.63	1hr	2.31	4.50
TVOC	8.86	4.5hrs	4.26	45mins	2.08	6.00
CO_2	410	40mins	368	30mins	1.11	1.33
$PM_{2.5}$	0.111	25mins	0.035	30mins	3.17	0.83

6. Possible Health Effects

Since many air fresheners contain volatile organic compounds (VOCs) and known toxins such as phthalates, esters in their formula, there is a high possibility for occupants to get affected by various illnesses. The results obtained, indicate that air fresheners have a major effect on TVOC concentration inside the room. Therefore, there is a high possibility for the occupants to get affected by diseases caused due to the exposure to high TVOC concentrations. (*Table 3*) Hence occupants could be susceptible to severe illnesses with the long term usage of air fresheners, especially in the enclosed spaces.

Table 3: Effects due to VOCs - from the study performed by the Natural Resources Defence Council (NRDC) [8], [9]

VOC	Effect
Formaldehyde	Lung irritants Asthma attacks Migraines
DEP*	Associated with changes in hormone levels and genital development in humans.
DBP*	Recognized as a reproductive toxicant by the National Toxicology Program and the State of California. It can lead to changes in genital development.
DIBP*	Associated with changes in male genital development.
DMP*	Inconclusive evidence has shown reproductive toxicity in animal studies.
DIHP*	Limited toxicity testing has shown that DIHP is probably a developmental and reproductive toxicant.

* *Refer **Chemical composition of air fresheners***

7. Conclusions and Recommendations

The IAQ status of an office room located in the structural testing laboratory of the Department of Civil Engineering, University of Moratuwa was studied after spraying 40 ml of air freshener. With the intention of studying the effect of air freshener spray, the concentrations of CO, VOC, CO_2 and $PM_{2.5}$ were monitored and results were analysed.

- From of the parameters considered, TVOC concentration inside the room has the most significant effect due to the air freshener spray. The TVOC concentration exceeded the permissible value at the instance of the spray and it lasted for approximately 2 hours.

- Although all the other parameters showed a rapid increase in the concentrations, they did not exceed the permissible limits.

- In each parameter except $PM_{2.5}$, the reached peak value in the air conditioned environment was more than that of the free running condition. (CO – 131 %, TVOC – 108 %, CO_2 – 11 %)

- The time taken for the dispersion was less for the free running condition than that of the air conditioned environment. (4.5 hours in air conditioned environment & 45 minutes in free running environment for TVOC, 4.5 hours in air conditioned environment and 1 hour in free running environment for CO)

- When these results are considered the usage of air fresheners cannot be recommended as a good habit.

- But the effect of air freshener sprays for the occupants under the free running condition is less than that of an air conditioned environment. Thus by improving the ventilation conditions, effect of this kind of harmful products can be minimized.

- Alternatively, air fresheners which do not contain the harmful compounds, can be introduced to minimize the effect of toxicity. Water based air fresheners can be recommended as a solution to this.

- Natural fragrances such as flowers can be recommended to gain pleasant odor.

- Better building operational practices should be maintained. Since the air fresheners are used to impart a pleasant odor, instead of using artificial fragrances, clean environments can be maintained. Furthermore, air fresheners should not be used to suppress any bad odour.

- In air conditioned environments, opening the windows for at least half an hour before switching on the AC, is a better operational practice.

- Proper maintenance of the Air Conditioners used inside the rooms to improve IAQ is also recommended.

- Usage of Air Conditioners which has a considerable amount of fresh air recharge can be recommended.

- The productivity of the offices and institutions can be enhanced by improving indoor air quality according to the recommendations given above. [10]

Acknowledgements

The authors wish to gratefully acknowledge the funds allocated by University of Moratuwa to purchase equipment and the support given by the staff of Department of Civil Engineering, University of Moratuwa.

References:

[1] Perera T.M., Jayasinghe C., Perera S.A.S, Rajapaksa S.W., Indoor Air quality and human activities in buildings

[2] Anne C. Steinemann, Fragranced consumer products and undisclosed ingredients. Environmental Impact Assessment Review 29 (2009) 32 – 38

[3]http://www.chm.bris.ac.uk/motm/ethylacetate/smells.htm

[4]http://www.easy-aromatherapy-recipes.com/essential-oils-perfume.html

[5] www.ashrae.org

[6] www.osha.gov

[7] www.who.int

[8] Ralph Scott, "Air Freshener, Indoor Air Quality & Federal Policy", 2008 National Healthy Homes Conference: September 15-17, 2008 in Baltimore, MD.

[9] National Resource Defence Council (www.nrdc.org/policy)

[10] C.K. Chau, W.K. Hui, M.S. Tse, Evaluation of health benefits for improving indoor air quality in workplace. Environment International 33 (2007) 186 - 198