Evaluating air quality with and without air fresheners

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Abstract

Air fresheners emit a range of volatile organic compounds, which can include hazardous air pollutants. Exposure to air fresheners has been associated with health problems such as migraine headaches, respiratory difficulties, and asthma attacks. To reduce pollutant exposures and potential adverse effects, air fresheners can be discontinued from use within indoor environments. However, little is known about how much air quality can be improved and over what time. This study evaluates the effects of air fresheners on air quality, with a focus on d-limonene, a prevalent and dominant compound in air fresheners, and one that can generate hazardous air pollutants. Using workplace environments, the study analyses and compares d-limonene concentrations in restrooms that use air fresheners, that discontinue the use of air fresheners, and that do not use air fresheners. In restrooms that use air fresheners, d-limonene concentrations averaged 6.78 $\mu g/m^3$ compared with 0.84 $\mu g/m^3$ in restrooms that do not use air fresheners. Further, after discontinuing the use of air fresheners, d-limonene concentrations decreased up to 96% within two weeks, with an average reduction of 81% and an average concentration down to 1.17 $\mu g/m^3$. These findings suggest that a straightforward strategy, such as ceasing the use of air fresheners, can produce measurable benefits for indoor air quality.

Key Words: air fresheners, fragrance, fragrance-free, restrooms, volatile organic compounds, indoor air quality

Introduction

Volatile organic compounds (VOCs) are a main category of air pollutants that typically occur at much higher concentrations indoors than outdoors (Goodman et al. 2017). A primary source of indoor VOCs are common fragranced consumer products, such as air fresheners (Steinemann 2015, 2017a). Emissions from fragranced products used indoors can also migrate outdoors and contribute to the formation of urban smog (McDonald et al. 2018).

Air fresheners are widely used throughout society in a range of indoor environments including offices, schools, health care facilities, stores, and restrooms (Steinemann 2017a). All types of air fresheners (e.g., sprays, gels, solids, oils, diffusers), including so-called green and organic air fresheners, can emit potentially hazardous VOCs (Steinemann 2015, 2017a; Kim et al. 2015; Uhde and Schulz 2015).

Air fresheners typically consist of dozens of different VOCs, such as terpenes (e.g., limonene, alpha-pinene, beta-pinene, gamma-terpinene, and linalool), ethanol, acetone, and acetaldehyde (Steinemann 2015; Uhde and Schulz 2015; Jo et al. 2008). In addition, terpenes can react with ozone to generate hazardous pollutants such as formaldehyde (Nazaroff and Weschler 2004). Prior studies have found that, among all air freshener compounds, limonene is typically the most common, at the highest concentration, or at the highest emission rate (Steinemann 2015; Uhde and Schulz 2015; Jo et al. 2008).

Exposure to emissions from air fresheners has been associated with adverse health effects in the general population and in vulnerable sub-populations. National population studies in the United States (US), Australia (AU), the United Kingdom (UK), and Sweden (SE) found that, on average, 17.4% of adults report adverse health effects from air fresheners and deodorizers (Steinemann 2016, 2017b, 2018a, 2018b, 2019a, b). Of those 17.4 % reporting adverse effects, the most common health problems were respiratory difficulties (50.6%), mucosal symptoms (35.8%) migraine headaches (30.8%), skin problems (26.2%), and asthma attacks (23.7%) (Steinemann 2019a).

Among vulnerable sub-populations, reports of adverse health effects are higher. For instance, across the US, AU, UK and SE, on average, 36.7% of asthmatic adults report adverse health effects, such as respiratory difficulties (58.0%) and asthma attacks (40.3%), from exposure to air fresheners and deodorizers (Steinemann and Goodman 2019). Across the US, AU, and UK, on average, 62.9% of autistic adults report adverse health effects, such as migraine headaches (37.0%) from exposure to air fresheners and deodorizers (Steinemann 2018c).

Air fresheners are also associated with loss of access in society. Across the US, AU, UK and SE, 13.3% of adults are unable or reluctant to use restrooms in a public place if it has an air freshener, deodorizer, or scented product. Further, 17.0% of adults enter a business and then want to leave as quickly as possible if they smell air fresheners or a fragranced product (Steinemann 2019a).

To reduce potential exposures and adverse effects, a typical strategy is to remove, disconnect, or otherwise restrict the use of air fresheners. However, we lack information on the effectiveness of ceasing the use of air fresheners on air quality, and a quantitative comparison between indoor environments that use air fresheners with those that don't use air fresheners.

The purpose of this study is to investigate and evaluate the effects on air quality from the use, discontinued use, and non-use of air fresheners. Specifically, it will analyze and compare the concentrations of air freshener chemicals (1) within restrooms that use air fresheners, (2) within those same restrooms after air fresheners are discontinued, and (3) within similar restrooms that did not use air fresheners. Results of this study provide a scientific basis for a practicable approach to potentially improve both indoor and outdoor air quality, reduce personal exposures and possible health risks, and improve societal access.

Methods

The study was conducted within eight restrooms located within engineering buildings at the University of Melbourne, Australia. The restrooms are designated as #1–8 for this paper. Air fresheners were installed and operating in restrooms #1–4. No air fresheners were installed or operating in restrooms #5–8. Characteristics of the restrooms are described in Supplementary Table S1. This study received ethics approval from The University of Melbourne (Application number: 1954006.1).

The same type of air freshener was used in all four restrooms (#1–4). Each air freshener consisted of a plastic housing unit secured to the wall approximately two metres above floor level, a pressurized fragrance canister (250 ml), and a battery powered programmable control module that activated the canister's spray nozzle at regular intervals (i.e., 10 or 15 minutes) between 8:00 am and 11:59 pm.

The experimental and sampling protocol proceeded as follows. Baseline air quality measurements were collected within all restrooms #1–8 on Day 1. After these baseline samples were collected, air fresheners were discontinued from use (pressurized cannisters removed) in restrooms #1–4 at the end of Day 1. To assess the attenuation of air freshener chemicals, samples were collected in restrooms #1–4 on Days 3, 7, and 14. For comparison with restrooms that did not use air fresheners, samples were also collected in restrooms #5–8 on Day 14.

All sampling was conducted after normal business hours, in the late evening, to avoid contact with people. Signs were posted to prevent entrance into the restrooms. In addition, special precautions were taken to minimise the potential for introduction of chemicals into the restrooms. For instance, although the restrooms were cleaned daily, this occurred in the early morning hours, and typically at least nine hours before any sampling. Also, cleaning staff had been asked to minimize the use of fragranced cleaning products in the restrooms.

Samples were collected following USEPA compendium methods TO 17 (US EPA 1999). For VOCs (i.e., d-limonene), a single multi-adsorbent tube was connected to a sampling pump at a flow rate of approximately 150 mL per minute for 1 h, to collect approximately 9 L of air. Temperature, relative humidity, and barometric pressure were measured using a portable monitor. In all restrooms, the air sampling point was approximately 1.6 m above floor level, and approximately 1.5 m from the air freshener. This location was chosen to approximate breathing zone of restroom occupants, and to provide a secure location for the aluminium ducting, sampling pump, and monitor. Analysis and reporting of VOCs follows methods previously detailed (Goodman et al. 2019).

For the VOC analyses of samples, the study focused on d-limonene because it is (a) a prevalent and dominant VOC across all types of air fresheners, (b) associated with adverse health effects and classified as a potentially hazardous compound (SWA 2018), and (c) a terpene that readily reacts with ozone to generate a range of secondary hazardous air pollutants.

The air freshener used in restrooms #1–4 was analysed for its VOC emissions using gas chromatography/mass spectrometry (GC/MS) headspace analysis, according to methods previously described (Nematollahi et al. 2018). The analysis confirmed the presence of 54 VOCs, including d-limonene (Supplementary Table 2).

Results and Discussion

Concentrations of d-limonene at each phase of sampling and at each restroom are provided in Table 1.

In restrooms that used air fresheners (#1–4), the concentrations of d-limonene ranged from 5.15 μg/m^3 to 9.68 μg/m^3 (mean 6.78 μg/m^3) on Day 1. After discontinuing use of air fresheners in those same restrooms, the concentrations of d-limonene ranged from (a) 0.23 μg/m^3 to 0.72 μg/m^3 on Day 3, (b) 0.35 μg/m^3 to 1.31 μg/m^3 on Day 7 and (c) 0.24 μg/m^3 to 2.99 μg/m^3 (mean 1.17 μg/m^3) on Day 14.

In restrooms that did not use air fresheners (#5–8), the concentrations of d-limonene ranged from 0.23 μg/m^3 to 2.29 μg/m^3 (mean 0.84 μg/m^3) on Day 1, and from 0.60 μg/m^3 to 1.34 μg/m^3 (mean 1.29 μg/m^3) on Day 14.

Key findings are as follows: (1) After air fresheners were discontinued from use, concentrations of d-limonene decreased up to 96% (average 81%) over two weeks, and major reductions (i.e., 92%) were accomplished by Day 3. (2) For all samples in all restrooms after air fresheners were discontinued or were not used, d-limonene concentrations were lower than any of the initial samples when air fresheners were in use. (3) After air fresheners were discontinued from use, concentrations of d-limonene approached the lower levels of restrooms that had not used any air fresheners.

Thus, these findings suggest that discontinuing the use of air fresheners can have an almost immediate benefit for air quality by reducing d-limonene concentrations. These findings are supported by a prior study of dryer vent emissions (Goodman et al. 2019), which found d-limonene concentrations up to 118 μg/m^3 during use of fragranced laundry products, and less than 1 μg/m^3 during use of fragrance-free laundry products. After switching from fragranced to fragrance-free products for four weeks, concentrations of d-limonene decreased as much as 99.7% (mean 79.1%).

A strength of this current study is that it used real-world environments: restrooms within a workplace. A further strength is that the approach is relatively straightforward and cost effective to implement. Thus, results indicate the practicably achievable improvements in air quality. However, a limitation is that it was not possible to control for all possible confounding factors. This may help to explain some of the anomalous datapoints (e.g., #2 and #3 Day 7, and #2 Day 14). For instance, an individual may have entered the restroom immediately prior to sampling and used or was wearing a fragranced product. Also, this study examined just one type of air freshener over just two weeks. Future research can examine different types of air fresheners over longer periods of time.

Conclusion

This study indicated improvements to air quality, in terms of d-limonene concentrations, after discontinuing the use of air fresheners in restrooms. Reductions in air freshener use may also reduce the formation and concentrations of secondary pollutants. Findings from this study can provide an important foundation for future research to help reduce VOC emissions and exposures.

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Table 1. Concentrations and reductions of d-limonene during use, discontinued use, and no use of air fresheners

Restroom	Air freshener used (Day 1) (μg/m³)	No air freshener used (Day 1) (μg/m³)	Air freshener discontinued (Day 3) (μg/m³)	Reduction in d-limonene on Day 3 (Day 1-Day 3)/(Day 1) (%)	Air freshener discontinued (Day 7) (μg/m³)	Reduction in d-limonene on Day 7 (Day 1-Day 7)/(Day 1) (%)	Air freshener discontinued (Day 14) (μg/m³)	Reduction in d-limonene on Day 14 (Day 1-Day 14)/(Day 1) (%)	No air freshener used (Day 14) (μg/m³)
#1	9.68	-	0.72	93%	0.74	92%	0.72	93%	-
#2	5.87	-	0.24	96%	0.95	84%	2.99	49%	-
#3	5.15	-	0.83	84%	1.31	75%	0.72	86%	-
#4	6.43	-	0.23	96%	0.35	95%	0.24	96%	-
mean	6.78	-	0.51	92%	0.83	86%	1.17	81%	-
#5	-	2.29	-	-	-	-	-	-	1.34
#6	-	0.48	-	-	-	-	-	-	0.71
#7	-	0.23	-	-	-	-	-	-	0.60
#8	-	0.36	-	-	-	-	-	-	2.50
mean	-	0.84	-	-	-	-	-	-	1.29

Table S1. Description of each restroom and measurements during sampling.

Restroom Number	Air Freshener Use	Description of all male restroom sampling locations	Dimensions L x W (m), [Area] (m^2)	Ceiling Height (m)	Volume (m^3)	Day sample collected	Pres (hPa)	Temp (°C)	RH (%)
#1	Yes	This restroom contains a partially enclosed toilet cubicle (0.99 m x 1.49 m), a urinal (0.81 m wide), and a wash basin installed in a bench (1.17 m wide).	2.78 x 1.74 [4.84]	2.43	11.76	Day 1	99.52	19.4	44.7
						Day 3	101.6	18.2	50.7
						Day 7	102.3	18.2	46.8
						Day 14	101.3	20.4	47.4
#2	Yes	This restroom contains a fully enclosed toilet cubicle (0.86 m x 3.04 m), a urinal (1.26 m wide) and two wash basins installed in a bench (1.65 m wide).	3.04 x 2.73 [8.29]	2.44	20.22	Day 1	99.53	20.3	43.8
						Day 3	101.6	19.0	48.9
						Day 7	102.3	18.5	45.2
						Day 14	101.3	21.9	50.6
#3	Yes	This restroom contains three partially enclosed toilet cubicles (0.85 m x 1.38 m) and four wash basins installed in a bench (5.20 m).	3.60 x 2.42 [8.71]	2.75	23.95	Day 1	99.65	19.1	52.0
						Day 3	101.7	18.8	51.2
						Day 7	102.3	18.5	-
						Day 14	101.4	22.1	47.8
#4	Yes	This restroom contains a toilet cubicle (0.895 m x 2.02 m), a urinal (1.26 m), and two wash basins installed in a bench (1.68 m).	3.04 x 2.74 [8.33]	2.43	20.24	Day 1	99.7	19.2	55.1
						Day 3	101.7	18.8	49.5
						Day 7	102.3	18.7	44.6
						Day 14	101.5	20.6	49.4
#5	No	This restroom contains a partially enclosed toilet cubicle (0.85 m x 1.73 m), a urinal (2.78 m), and two wash basins installed in a bench (1.61 m wide).	2.78 x 3.33 [9.26]	2.40	22.22	Day 1	100.5	22.2	36.1
						Day 14	100.7	23.3	49.3
#6	No	This restroom contains a partially enclosed toilet (each 0.87 m x 1.83 m), a urinal (1.27 m wide) and a wall mounted basin.	4.17 x 2.4 [10.01]	2.98	29.82	Day 1	100.7	21.1	35.9
						Day 14	100.8	20.9	55.3
#7	No	This restroom contains a fully enclosed toilet (0.88 m x 1.53 m), a urinal (1.27 m wide) and two wash basins installed in a bench (2.05 m wide).	3.13 x 3.03 [9.48]	2.38	22.56	Day 1	100.5	20.6	39.1
						Day 14	100.6	23.3	47.4
#8	No	This restroom contains three partially enclosed toilets (each ~0.88 m x 1.5 m), a urinal (1.45 m wide) and a wall mounted basin.	4.23 x 2.72 [11.50]	2.80	32.20	Day 1	100.6	21.2	34.9
						Day 14	100.6	21.8	53.1

Table S2. GC/MS headspace analysis of VOCs emitted from the air freshener in this study.

Compound	CAS #
Butane*	106-97-8
Ethanol*	64-17-5
Limonene*	138-86-3
Methanol*	67-56-1
Isopentane*	78-78-4
2-Methyl-1-propene*	115-11-7
Pentane*	109-66-0
beta-Myrcene	123-35-3
beta-Pinene	127-91-3
3,7-Dimethyldecane	17312-54-8
5-Propyldecane	17312-62-8
alpha-Pinene	80-56-8
2,5-Dimethyldodecane	56292-65-0
5-Methylundecane	1632-70-8
Methyl phenylcarbinyl acetate	93-92-5
2,4,6-Trimethyl-octane	62016-37-9
6-Methylundecane	17302-33-9
2,3,4-Trimethyldecane	62238-15-7
Linalyl propionate	144-39-8
Linalyl acetate	115-95-7
Diisopentyl carbonate	2050-95-5
2,6-Dimethyl octane	2051-30-1
3,6-Dimethylundecane	17301-28-9
2,2,3,3,5,6,6-Heptamethylheptane	7225-67-4
Linalool	78-70-6
Hexane*	110-54-3
Sabinene	3387-41-5
3,5-Dimethylheptane	926-82-9
2-Methylpentane*	107-83-5
2,2,4,6,6-Pentamethylheptane	13475-82-6
6-Ethyl-undecane	17312-60-6
cis-1,2-Dimethylcyclopropane	930-18-7
3-Methylpentane*	96-14-0
Ethyl butyrate	105-54-4
Ethyl 2-methylbutyrate	7452-79-1
Linalyl anthranilate	7149-26-0
5,6-Dimethylundecane	17615-91-7
Ethyl formate*	109-94-4
Dodecane	112-40-3
4-Methyldodecane	6117-97-1
Methylcyclopentane	96-37-7
2,3-Dimethyloctane	7146-60-3
4-Methylnonane	17301-94-9
Acetone*	67-64-1
2,5,6-trimethyloctane	62016-14-2
3-Carene	13466-78-9
2,2,6-Trimethyloctane	62016-28-8
Cyclohexane*	110-82-7
3-Methylnonane	5911-04-6
Cyclopentane*	287-92-3
Heptane*	142-82-5
Methylcyclohexane*	108-87-2
5-Butylnonane	17312-63-9
3-Methylundecane	1002-43-3

Chemicals are listed in descending order according to chromatograph peak area.
* Classified as potentially hazardous under Safe Work Australia, Hazardous Chemical Information System (SWA 2018).