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Pandemic Products and Volatile Chemical Emissions

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Abstract

The recent pandemic (COVID-19) has seen a sweeping and surging use of products intended to clean and disinfect, such as air sprays, hand sanitizers, and surface cleaners, many of which contain fragrance. However, exposure to fragranced cleaning products has been associated with adverse effects on human health. Products can emit a range of volatile chemicals, including some classified as hazardous, but relatively few ingredients are disclosed to the public. Thus, relatively little is known about the specific emissions from these products. This study investigates the volatile organic compounds (VOCs) emitted from “pandemic products” that are being used frequently and extensively in society. In addition, among these emissions, this study identifies potentially hazardous compounds, compares so-called green and regular versions of products, and examines whether ingredients are disclosed to the public. Using gas chromatography/mass spectrometry, 26 commonly used pandemic products, including 13 regular and 13 so-called green versions, were analyzed for their volatile emissions. Product types included hand sanitizers, air disinfectants, multipurpose cleaners, and handwashing soap. All products were fragranced. The analyses found the products collectively emitted 399 VOCs with 127 VOCs classified as potentially hazardous. All products emitted potentially hazardous compounds. Comparing regular products and green products, no significant difference was found in the emissions of the most prevalent compounds. Further, among the 399 compounds emitted, only 4% of all VOCs and 11% of potentially hazardous VOCs were disclosed on any product label or safety data sheet. This study reveals that pandemic products can generate volatile emissions that could pose risks to health, that could be unrecognized, and that could be reduced, such as by using fragrance-free versions of products.

Keywords: pandemic, coronavirus, fragranced consumer products, volatile organic compounds, emissions, cleaning, disinfectants, hand sanitizers

Introduction

Cleaning and disinfection products are common in society, especially with increased frequency and extent of use during the coronavirus pandemic. The preponderant use of products—such as air fresheners and disinfectants, hand sanitizers and soaps, and multipurpose surface cleaners—appears to focus on the virus and not necessarily emissions, with the assumption that more use is better. Consequently, chemical exposures from products can be increasing across the population. However, and paradoxically, products intended to reduce risks to health may actually be posing risks to health, albeit in other ways. Important questions arise, such as the following: What is actually emitted from the products? Do any chemicals pose possible hazards? Are so-called green or natural products any different? Are product ingredients fully disclosed to the public?

This study investigates emissions from a range of cleaning and disinfectant products that have been commonly used during the pandemic, which this article terms “pandemic products.” The study pursues four main objectives: (a) to analyze the volatile organic compounds (VOCs) emitted from a set of typical fragranced pandemic products, (b) to identify the compounds classified as potentially hazardous, (c) to compare emissions between regular and so-called green versions of products, and (d) to assess whether compounds emitted are disclosed on product labels or safety data sheets. Results from this study can provide a scientific foundation to understand emissions from the use of pandemic products, and ways to reduce risks.

Cleaning and disinfection products have a history of associations with effects on health. Nazaroff and Weschler (2004) synthesize evidence of adverse health outcomes linked to chemical exposures from the use of cleaning products and air fresheners. In addition, use of fragranced cleaning products and air disinfectants has been associated with migraine headaches (e.g., Silva-Néto et al. 2014; Steinemann and Nematollahi 2020), asthma attacks and exacerbations (e.g., Zock et al. 2007; Weinberg et al. 2017; Steinemann and Goodman 2019), childhood wheeze (e.g., Parks et al., 2020; Sherriff et al. 2005), and additional health problems related to neurological, gastrointestinal, respiratory, dermatological, and immune systems (e.g., Steinemann 2019a).

In recent work, nationally representative population-based studies, across the United States, Australia, the United Kingdom, and Sweden, found that 32.2% of the general population on average (34.7%, 33.0%, 27.8%, 33.1%, respectively) report health problems when exposed to fragranced consumer products, including air fresheners, deodorizers, hand soaps, hand sanitizers, all-purpose cleaners, and disinfectants (Steinemann 2018a, b, 2017a, 2016).

Further, across these four countries, 17.4% of the general population, and 36.7% of asthmatics, report health problems when exposed to air fresheners and deodorizers. Also, 15.7% of the general population, and 32.9% of asthmatics, report health problems from being in a room after it has been cleaned by fragranced products (Steinemann 2019a, Steinemann and Goodman 2019).

In prior chemical analyses and comparisons of fragranced and fragrance-free cleaning products (Steinemann 2015; Nematollahi et al. 2019), all of the fragranced products emitted terpenes (e.g., limonene, alpha-pinene, beta-pinene), but none of the fragrance-free products emitted terpenes. Terpenes can act as both primary pollutants as well as react with ozone to generate a range of secondary pollutants, such as formaldehyde.

Methods

For this study, 26 common cleaning and disinfectant products, widely used and sold in two countries (the United States and Australia), were randomly selected and analyzed for their emissions. Product types were hand sanitizers, air disinfectants, multipurpose cleaners and disinfectants, and handwashing soap; each of the products was fragranced (see Table 1).

The products selected include both “green” and “regular” versions. Herein, the term “green” refers to products with the claim of being “green” or related terms, such as “natural” or “organic.” The term “regular” refers to products other than those in the “green” category.

Criteria for selection as a “pandemic product” were (i) a government issued public health recommendation for a product type to be used more frequently and extensively for purposes against the coronavirus, (ii) a government issued approval for a specific product to be used for purposes against the coronavirus, or (iii) both.

To determine the volatile ingredients, headspace gas chromatography/mass spectrometry (GC/MS) was used to analyze the VOCs emitted from the products. The chromatogram for each product was scanned to identify the highest concentration VOCs (top 20 peaks). Compound identification was based on the mass spectral library of the National Institute of Standards and Technology NIST Version 2.0 (see Nematollahi et al. 2018; Steinemann et al. 2011 for additional details on the analytic methods). Chromatographic data for each product, as reported in supplementary tables of Nematollahi et al. (2019) and Steinemann (2015), were reanalyzed for the purposes of this study, including new analyses of VOC prevalences, hazardous compound classifications, comparisons of regular and green products, ingredient disclosures, and product claims related to the pandemic.

Potentially hazardous VOCs were identified according to classifications of (i) hazardous air pollutants (HAPs), United States Environmental Protection Agency (EPA 2017), including carcinogenic HAPs (EPA 2018), (ii) Hazardous Chemical Information System (HCIS), Safe Work Australia (SWA 2020), and (iii) asthmagens, Association of Occupational and Environmental Clinics (AOEC 2020). This analysis was performed to identify ingredients that are classified as potentially hazardous under one or more of these criteria. However, this analysis does not imply an evaluation of product safety or risks. It also does not imply that these VOCs are the only potentially hazardous compounds emitted or generated from the products.

Results

VOCs emitted and most prevalent VOCs

A summary of VOCs emitted across the 26 cleaning products, both regular and green, is provided in Table 2. In this paper, the term “VOC occurrences” refers to the number of individual VOCs emitted from the products, such that each VOC occurrence represents a single volatile ingredient in a single product. The term “VOC identities” refers to the number of distinctly named VOCs emitted from the products, such that each VOC identity represents a compound, according to name and CAS number, that occurs in one or more of the products.

Across the 26 cleaning products, 399 VOCs were emitted (occurrences), representing 172 VOCs identities. The most prevalent VOCs (in at least 40% of all products) were limonene, ethanol, alpha-pinene, beta-pinene, and acetaldehyde (Table 3). In both “regular” and “green” products, the most prevalent VOC was limonene. Data on emissions from each specific product, as well as the most prevalent VOCs across the products, are provided in Supplementary Tables 1 and 2.

Potentially hazardous emissions

For the 399 VOCs (occurrences) emitted collectively from the 26 products, 127 VOCs are classified as potentially hazardous, representing approximately 30% of all VOC ingredients. All products emitted between 1 and 4 VOCs classified as potentially hazardous.

For the 172 VOCs (identities) emitted across the 26 products, 46 VOCs are classified as potentially hazardous. The most prevalent potentially hazardous VOCs (in at least 25% of all cleaning products) were limonene, ethanol, acetaldehyde, 3-carene, and methanol (Table 4).

Comparison of VOCs emitted from regular and green products

Among the most prevalent VOCs, no significant difference was found in the VOC identities and occurrences between the regular and green products ($p = 0.11$, t test). In addition, among the most prevalent potentially hazardous VOCs, no significant difference was found in VOC identities and occurrences between regular and green products ($p = 0.17$, t test). This comparison followed the convention of previously published work (e.g., Steinemann 2015, Nematollahi et al. 2019) that analyzed and compared regular and green products.

Comparison of VOCs emitted and ingredients disclosed

Among the 399 VOCs emitted from the products, only 16 were listed on any product label or safety data sheet. In addition, among the 127 VOCs classified as potentially hazardous emitted from the products, only 14 were listed on any product label or safety data sheet (Table 2). Thus, only 4% of all VOCs, and 11% of the potentially hazardous VOCs, were disclosed to the public on product labels or safety data sheets.

Discussion

This study found that fragranced pandemic products of all types, including both regular and green versions, emit numerous volatile chemicals, some of which are classified as hazardous, and few of which are disclosed to the public. Thus, chemical emissions and associated risks may be largely unrecognized. Results are especially concerning given that chemical exposures may be involuntary, and affect vulnerable populations such as children, the elderly, and individuals in institutions and care facilities.

Our findings are consistent with prior studies of fragranced cleaning products and air fresheners (Steinemann 2015, 2017b, 2019a, b; Steinemann et al. 2011; Nematollahi et al. 2019, 2018; Uhde and Schulz 2015) as follows. First, terpenes (e.g., limonene) were the most commonly emitted ingredients. Second, all types of products, even green versions, emitted potentially hazardous VOCs. Third, no significant difference was found in emissions between regular and green products. Fourth, across the studies, fewer than 10% of volatile ingredients were disclosed to the public on product labels, safety data sheets, websites, or elsewhere.

However, this lack of full ingredient disclosure is permissible. Cleaning products are not required to disclose all of their specific ingredients. Further, a “fragrance” in a product is also exempted from full ingredient disclosure, even though a fragrance is typically a complex mixture of dozens of chemicals. Although products regulated as drugs or cosmetics need to list ingredients, the general term “fragrance” may be listed, instead of specific compounds (see Steinemann 2009; Lunny et al. 2017).

Terpenes are characteristic of fragranced consumer products. In comparisons of fragranced and fragrance-free versions of products, terpenes are the most prevalent compounds in fragranced products, but they are absent in fragrance-free products (Steinemann 2015;

Nematollahi et al. 2019). Terpenes are not only primary pollutants, but they also generate a range of secondary pollutants. Thus, choosing products without fragrance could reduce exposures to terpenes and other fragrance compounds, which can include potentially hazardous air pollutants and allergens. To note, unscented products are not necessarily fragrance-free, as they can contain fragrance compounds to cover the scent (Steinemann 2019a).

Limitations of the study include the following. The GC/MS headspace analysis identified volatile ingredients that are directly emitted from the product without interactions with ambient air. Thus, the analysis would not have captured a range of secondary pollutants, such as through terpene-ozone interactions, that could contribute to product risks. The study also focused on volatile organic compounds, and products can contain other classes of chemicals, such as semivolatile organic compounds. The GC/MS analysis examined emissions from a single product, whereas emissions from multiple products used together could generate chemical reactions that pose additional risks. Finally, while the study identified specific compounds as well as broader public health issues, the analysis was not intended as a quantification of risks from product use.

Results from the study lead to a question: Are there alternative products that could provide equivalent functionality against the virus but without emissions that may be problematic for health? Given that fragranced cleaning products have been associated with reports of health problems, and that fragrance in product is added for aesthetics, fragrance-free products could offer reasonable alternatives.

Conclusions

This study provides findings on the VOCs emitted by 26 products frequently and extensively used during the pandemic. The analysis found 399 VOC ingredients, with 127 VOCs classified as potentially hazardous, emitted from the products. Limonene was the most commonly emitted compound, found in 80% of products. Emissions of the most prevalent potentially hazardous VOCs from regular and green fragranced products were not significantly different. Only 4% of all VOCs and 11% of potentially hazardous VOCs were listed on any product label. Results of this study can help to improve awareness about emissions from pandemic products, and provide a foundation for understanding and reducing risks of product use.

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Table 1: Types of tested products

	Hand sanitizer	Air disinfectant	Multipurpose cleaners and disinfectants	Handwashing soap	Total
Regular	1	3	5	4	13
Green	1	2	6	4	13
Total	2	5	11	8	26

Table 2: VOCs emitted from products*

Type	Number of products	Emitted		Listed (on product label or safety data sheet)	
		All VOCs	Potentially Hazardous VOCs	All VOCs	Potentially Hazardous VOCs
Regular	13	211 occurrences 122 identities	61 occurrences 35 identities	4 occurrences 3 identities	4 occurrences 3 identities
Green	13	188 occurrences 96 identities	58 occurrences 24 identities	7 occurrences 5 identities	5 occurrences 3 identities
Total	26	399 occurrences 172 identities	127 occurrences 46 identities	16 occurrences 7 identities	14 occurrences 5 identities

*"VOC occurrences" refers to the number of individual VOCs emitted from the products.

"VOC identities" refers to the number of distinctly named VOCs emitted from one or more of the products.

Table 3: Most prevalent VOCs emitted from products

Compound	CAS #	Prevalence (# of products)		
		Total (n=26)	Regular (n=13)	Green (n=13)
<u>All products (n=26)</u>				
Limonene*	138-86-3	21	10	11
Ethanol*	64-17-5	17	7	10
alpha-Pinene	80-56-8	13	7	6
beta-Pinene	127-91-3	12	8	4
Acetaldehyde*	75-07-0	11	4	7
Eucalyptol	470-82-6	11	4	7
gamma-Terpinene	99-85-4	11	5	6
beta-Myrcene	123-35-3	10	1	9
beta-trans-Ocimene	3779-61-1	10	3	7
Camphene	79-92-5	10	5	5
3-Carene*	13466-78-9	8	4	4
beta-Phellandrene	555-10-2	8	5	3
Linalool	78-70-6	8	4	4
alpha-Phellandrene	99-83-2	7	3	4
Methanol*	67-56-1	7	3	4
<u>Regular products (n=13)</u>				
Limonene*	138-86-3		10	
beta-Pinene	127-91-3		8	
Ethanol*	64-17-5		7	
alpha-Pinene	80-56-8		7	
gamma-Terpinene	99-85-4		5	
Camphene	79-92-5		5	
beta-Phellandrene	555-10-2		5	
Acetaldehyde*	75-07-0		4	
Eucalyptol	470-82-6		4	
3-Carene*	13466-78-9		4	
Linalool	78-70-6		4	
6-Methyl-5-hepten-2-one	110-93-0		4	
o-Cymene	527-84-4		4	
Butane*	106-97-8		4	
alpha-Terpinene	99-86-5		4	
<u>Green products (n=13)</u>				

Limonene*	138-86-3	11
Ethanol*	64-17-5	10
beta-Myrcene	123-35-3	9
Acetaldehyde*	75-07-0	7
Eucalyptol	470-82-6	7
beta-trans-Ocimene	3779-61-1	7
alpha-Pinene	80-56-8	6
gamma-Terpinene	99-85-4	6
Camphene	79-92-5	5
beta-Pinene	127-91-3	4
3-Carene*	13466-78-9	4
Linalool	78-70-6	4
alpha-Phellandrene	99-83-2	4
Methanol*	67-56-1	4
Acetone*	67-64-1	4

*Classified as potentially hazardous

Table 4: Potentially hazardous VOCs emitted from the products

Compound	CAS #	Prevalence (# of Products)			HAPs	SWA	Asthmagens
		Total (n=26)	Regular (n=13)	Green (n=13)			
Limonene	138-86-3	21	10	11		✓	
Ethanol	64-17-5	17	7	10		✓	
Acetaldehyde**	75-07-0	11	4	7	✓	✓	
3-Carene	13466-78-9	8	4	4			✓
Methanol	67-56-1	7	3	4	✓	✓	
Acetone	67-64-1	5	1	4		✓	
Butane	106-97-8	5	4	1		✓	
1-Octanol	111-87-5	3	0	3		✓	
Cyclohexane	110-82-7	3	2	1		✓	
Ethyl acetate	141-78-6	3	2	1		✓	
Pentane	109-66-0	3	1	2		✓	
(E)-citral	141-27-5	2	1	1		✓	
2-Methyl-2-propanol	75-65-0	2	2	0		✓	
Acetaldehyde diethyl acetal	105-57-7	2	1	1		✓	
beta-Citral	106-26-3	2	1	1		✓	
Butanone	78-93-3	2	1	1		✓	
Isopropyl alcohol	67-63-0	2	1	1		✓	
1,1-dichloroethylene	75-35-4	1	1	0	✓	✓	
2,4-Dimethylpentane	108-08-7	1	1	0		✓	
2-chlorotoluene	95-49-8	1	0	1		✓	
2-Methyl-1-propene	115-11-7	1	1	0		✓	
3-Methylhexane	589-34-4	1	0	1		✓	
5-Methylheptan-3-one	541-85-5	1	1	0		✓	
Allyl alcohol	107-18-6	1	1	0		✓	
Benzaldehyde	100-52-7	1	0	1		✓	
Benzyl alcohol	100-51-6	1	0	1		✓	
Butyraldehyde	123-72-8	1	0	1		✓	
Carbon Tetrachloride**	56-23-5	1	1	0	✓	✓	
Chloroform**	67-66-3	1	1	0	✓	✓	
Citral	5392-40-5	1	0	1		✓	
E-2-butene	624-64-6	1	1	0		✓	
Ethyl formate	109-94-4	1	0	1		✓	
Heptan-4-one	123-19-3	1	1	0		✓	
Heptane	142-82-5	1	1	0		✓	
Hexane	110-54-3	1	1	0	✓	✓	
Isoamyl acetate	123-92-2	1	1	0		✓	
Isobutane	75-28-5	1	1	0		✓	
Methyl acetate	79-20-9	1	0	1		✓	

Methyl isobutyl ketone	108-10-1	1	0	1	✓	✓	
N,N-dimethylacetamide	127-19-5	1	1	0		✓	
Octane	111-65-9	1	1	0		✓	
Propane	74-98-6	1	1	0		✓	
Propylene glycol butyl ether	5131-66-8	1	1	0		✓	
Styrene**	100-42-5	1	1	0	✓	✓	✓
Tetracarbonylnickel	13463-39-3	1	1	0		✓	✓
Toluene	108-88-3	1	1	0	✓	✓	

HAPs: Hazardous Air Pollutants (HAPs), United States Environmental Protection Agency (EPA 2017),

**Classified as possibly carcinogenic (2B) (EPA 2018)

SWA: Hazardous Chemical Information System (HCIS), Safe Work Australia (SWA 2020)

Asthmagens: Association of Occupational and Environmental Clinics (AOEC 2020)

Supplementary Table 1: VOCs emitted from each of the products

1. Hand sanitizer ^G

Compounds	CAS#
Acetaldehyde*	75-07-0
Methanol*	67-56-1
Ethanol*	64-17-5
alpha-Thujene	2867-05-2
beta-trans-Ocimene	3779-61-1
beta-Phellandrene	555-10-2
alpha-Pinene	80-56-8
beta-Myrcene	123-35-3
alpha-Phellandrene	99-83-2
Terpinolene	586-62-9
Limonene*	138-86-3
1-Isopropyl-4-methylbenzene	99-87-6
3-Carene*	13466-78-9
Eucalyptol	470-82-6
gamma-Terpinene	99-85-4

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

2. Hand sanitizer

Compounds	CAS#
Ethanol*	64-17-5
alpha-Pinene	80-56-8
Limonene*	138-86-3
beta-Pinene	127-91-3
Ethyl acetate*	141-78-6
Camphene	79-92-5
Acetaldehyde diethyl acetal*	105-57-7
Acetaldehyde*	75-07-0
alpha-Fenchene	471-84-1
1-Methyl-1,4-cyclohexadiene	4313-57-9
Cyclohexane*	110-82-7
Butanone*	78-93-3
Tricyclene	508-32-7
beta-Phellandrene	555-10-2
alpha-Terpinene	99-86-5
3-Methylenecyclohexene	1888-90-0
Butane*	106-97-8
2-Bornene	464-17-5
Bicyclo[4.1.0]hept-2-ene	2566-57-6
alpha-Phellandrene	99-83-2

*Classified as potentially hazardous.

3. Air disinfectant ^G

Compounds	CAS#
Ethanol*	64-17-5
Methanol*	67-56-1
(E)-citral*	141-27-5
beta-Citral*	106-26-3
6-Methyl-5-hepten-2-one	110-93-0
beta-Myrcene	123-35-3
Acetone*	67-64-1
Acetaldehyde*	75-07-0
Ethyl formate*	109-94-4
Acetaldehyde diethyl acetal*	105-57-7
Undecane	1120-21-4
Methyl (S)-2-methylbutanoate	53955-81-0
Dodecane	112-40-3
3-Buten-2-ol, 2-methyl-	115-18-4
2-chlorotoluene*	95-49-8

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

4. Air disinfectant/surface disinfectant ^G

Compound	CAS#
Ethanol*	64-17-5
Limonene*	138-86-3
Octanal	124-13-0
Allyl hexanoate	123-68-2
2-(cis-4-methylcyclohexyl)-2-propanol	7322-63-6
Decanal	112-31-2
Linalyl formate	115-99-1
Linalyl acetate	115-95-7
2-Nonenenitrile	29127-83-1
Citral*	5392-40-5
2-tert-Butylcyclohexanol	13491-79-7
Geraniol	106-24-1

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

5. Air disinfectant

Compound	CAS#
Ethanol*	64-17-5
alpha-Pinene	80-56-8
beta-Pinene	127-91-3
Ethyl acetate*	141-78-6
Limonene*	138-86-3
Cyclohexane*	110-82-7
alpha-Thujene	2867-05-2
Camphene	79-92-5
beta-Phellandrene	555-10-2

*Classified as potentially hazardous.

6. Air disinfectant

Compounds	CAS#
Ethanol*	64-17-5
Limonene*	138-86-3
Ethyl 2-methylbutyrate	7452-79-1
beta-Pinene	127-91-3
Ethyl isobutyrate	97-62-1
Prenyl acetate	1191-16-8
5-Methylheptan-3-one*	541-85-5
2,4-Dimethyl-3-cyclohexenecarboxaldehyde	68039-49-6
Acetaldehyde*	75-07-0
2-Methyl-2-propanol*	75-65-0
gamma-Terpinene	99-85-4
Isoamyl acetate*	123-92-2
alpha-Pinene	80-56-8
Linalool	78-70-6
6-Methyl-5-hepten-2-one	110-93-0
Trivertal	27939-60-2
o-Cymene	527-84-4
beta-Phellandrene	555-10-2
alpha-Thujene	2867-05-2

*Classified as potentially hazardous.

7. Air disinfectant

Compounds	CAS#
Acetone*	67-64-1
Propane*	74-98-6
Limonene*	138-86-3
Isobutane*	75-28-5
beta-Pinene	127-91-3
alpha-Pinene	80-56-8
gamma-Terpinene	99-85-4
2,2-Diethoxypropane	126-84-1
beta-Phellandrene	555-10-2
Butane*	106-97-8
o-Cymene	527-84-4
Isopropenyl formate	32978-00-0
alpha-Terpinene	99-86-5
alpha-Phellandrene	99-83-2
2-Methyl-2-propanol*	75-65-0
Camphene	79-92-5
2,4-Dimethylpentane*	108-08-7
Terpinolene	586-62-9
2,3-Dimethylpentane	565-59-3
E-2-butene*	624-64-6
(Z)-beta-ocimene	3338-55-4

*Classified as potentially hazardous.

8. Multipurpose cleaning/disinfectant supplies

Compounds	CAS#
Limonene*	138-86-3
beta-Pinene	127-91-3
Hexyl acetate	142-92-7
beta-trans-Ocimene	3779-61-1
Allyl hexanoate	123-68-2
6-Methyl-1,6-heptadiene	13643-06-6
Ethyl isobutyrate	97-62-1
Tetrahydrolinalool	57706-88-4
Myrtanyl acetate	29021-36-1
gamma-Terpinene	99-85-4
2-(6-Octynyl)-1,3-dioxolane	56741-65-2
Terpinyl acetate	80-26-2
Terpinolene	586-62-9
Dihydromyrcenol	18479-58-8
N-Benzoyloxycarbonyl-dl-norleucine	15027-13-1
Ethyl butyrate	105-54-4
Sabinene	3387-41-5
1-Isopropyl-2-methyl-3-(1-methylethylidene)cyclopropane	24524-51-4
Verdyl acetate	5413-60-5
Octanal	124-13-0

*Classified as potentially hazardous.

9. Multipurpose cleaning/disinfectant supplies

Compounds	CAS#
Carbon Tetrachloride*	56-23-5
Chloroform*	67-66-3
1,1-dichloroethylene*	75-35-4
Tetracarbonylnickel*	13463-39-3
Decane	124-18-5
N-Chlorodimethylamine	1585-74-6
4-tert-Butylcyclohexyl acetate	32210-23-4
6-Methyl-5-hepten-2-one	110-93-0
Diphenyl ether	101-84-8

*Classified as potentially hazardous.

10. Multipurpose cleaning/disinfectant supplies

Compounds	CAS#
Ethanol*	64-17-5
Limonene*	138-86-3
(E)-2,5-Dimethyl-1,6-octadiene	68702-25-0
Eucalyptol	470-82-6
4-tert-Butylcyclohexyl acetate	32210-23-4
1-(1,2-Dimethyl-cyclopent-2-enyl)-ethanone	70987-82-5
2-(2-Hydroxypropoxy)-1-propanol	106-62-7
1,3-Dimethyl-2-(1-methylethyl)cyclopentene	61142-32-3
1-[2-(Allyloxy)-1-methylethoxy]-2-propanol	55956-25-7
2,7-Dimethyl-1,7-octadiene	59840-10-7
1-Isopropyl-2,3-dimethyl-1-cyclopentene	7712-73-4
Cyclopropane, 1-methyl-2-(1-methylethyl)-3-(1-methylethylidene)-, cis-	24524-52-5
(E)-citral*	141-27-5
6-Methyl-5-hepten-2-one	110-93-0
Terpinyl acetate	80-26-2
trans-3-Isopropyl-6-methylcyclohexene	1124-26-1
Acetaldehyde*	75-07-0
Dihydromyrcenol	18479-58-8
beta-Citral*	106-26-3
Isocitronellene	85006-04-8

*Classified as potentially hazardous.

11. Multipurpose cleaning/disinfectant supplies ^G

Compounds	CAS#
Ethanol*	64-17-5
Limonene*	138-86-3
Methanol*	67-56-1
Ethyl acetate*	141-78-6
4-tert-Butylcyclohexyl acetate	32210-23-4
Methyl hexanoate	106-70-7
Hexyl acetate	142-92-7
Methyl valerate	624-24-8
Methyl laurate	111-82-0
Methyl butyrate	623-42-7
Hexyl propionate	2445-76-3
beta-Myrcene	123-35-3
Methyl propionate	554-12-1
Allyl heptanoate	142-19-8
Methyl acetate*	79-20-9

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

12. Multipurpose cleaning/disinfectant supplies^G

Compounds	CAS#
Limonene*	138-86-3
Ethanol*	64-17-5
beta-Myrcene	123-35-3
3-Methoxy-3-methylbutanol	56539-66-3
beta-Pinene	127-91-3
beta-trans-Ocimene	3779-61-1
Linalool	78-70-6
Methanol*	67-56-1
gamma-Terpinene	99-85-4
L-menthol	2216-51-5
Sabinene	3387-41-5
1-Octanol*	111-87-5
alpha-Fenchene	471-84-1
Camphene	79-92-5
3-Carene*	13466-78-9
Octanal	124-13-0
Menthone	10458-14-7
Terpinyl acetate	80-26-2
beta-trans-Ocimene	3779-61-1
1-Decanol	112-30-1

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

13. Multipurpose cleaning/disinfectant supplies^G

Compounds	CAS#
Limonene*	138-86-3
Ethanol*	64-17-5
beta-trans-Ocimene	3779-61-1
beta-Myrcene	123-35-3
Sabinene	3387-41-5
Octanal	124-13-0
Eucalyptol	470-82-6
gamma-Terpinene	99-85-4

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

14. Multipurpose cleaning/disinfectant supplies^G

Compounds	CAS#
Ethanol*	64-17-5
Methyl isobutyl ketone*	108-10-1
(E)-5-Tetradecene	41446-66-6
Acetone*	67-64-1
Acetaldehyde*	75-07-0
(E)-3-Tetradecene	41446-68-8
(Z)-7-tetradecene	41446-60-0

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

15. Multipurpose cleaning/disinfectant supplies

Compounds	CAS#
Propylene glycol butyl ether*	5131-66-8
Eucalyptol	470-82-6
N,N-dimethylacetamide*	127-19-5
4-tert-Butylcyclohexyl acetate	32210-23-4
Di-sec-butyl ether	6863-58-7
2,7-Dimethyl-2,7-octanediol	19781-07-8
(Z)-rose oxide	16409-43-1
3-Methoxy-3-methylbutanol	56539-66-3
Heptan-4-one*	123-19-3
3-Carene*	13466-78-9
2,3-Epoxyhexanol	90528-63-5
2-Nonenenitrile	29127-83-1

*Classified as potentially hazardous.

16. Multipurpose cleaning/disinfectant supplies^G

Compounds	CAS#
Eucalyptol	470-82-6
Limonene*	138-86-3
1,4-Cineole	470-67-7
Camphor	76-22-2
o-Cymene	527-84-4
beta-Pinene	127-91-3
alpha-Pinene	80-56-8
Butanone*	78-93-3
Butyraldehyde*	123-72-8
gamma-Terpinene	99-85-4
1-Methoxy-4-propylbenzene	104-45-0
Terpinolene	586-62-9
Cyclohexane*	110-82-7
2-Butoxyethanol	111-76-2
alpha-Phellandrene	99-83-2
Acetone*	67-64-1
Tridecane	629-50-5
Camphene	79-92-5
Dodecane	112-40-3

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

17. Multipurpose cleaning/disinfectant supplies

Compounds	CAS#
Limonene*	138-86-3
beta-Pinene	127-91-3
Isopropyl alcohol*	67-63-0
alpha-Pinene	80-56-8
6-Methyl-5-hepten-2-one	110-93-0
Acetaldehyde*	75-07-0
beta-Phellandrene	555-10-2
Methanol*	67-56-1
gamma-Terpinene	99-85-4
Ethanol*	64-17-5
3,4-Dimethyl-3-cyclohexene-1-carboxaldehyde	18022-66-7
alpha-Terpinene	99-86-5
Terpinolene	586-62-9
3-Carene*	13466-78-9
o-Cymene	527-84-4
alpha-Phellandrene	99-83-2
Allyl alcohol*	107-18-6
Decane	124-18-5
1,3,8-p-Menthatriene	21195-59-5
Styrene*	100-42-5

*Classified as potentially hazardous.

18. Multipurpose cleaning/disinfectant supplies^G

Compounds	CAS#
Isopropyl alcohol*	67-63-0
Acetone*	67-64-1
Ethanol*	64-17-5
2,7-Dimethyl-2,7-octanediol	19781-07-8
Eucalyptol	470-82-6
Acetaldehyde*	75-07-0
Limonene*	138-86-3

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

19. Handwashing soap/liquid

Compounds	CAS#
Diethyl phthalate	84-66-2
Benzyl acetate	140-11-4
Methanol*	67-56-1
(Z)-7-tetradecene	41446-60-0
2-tert-Butylcyclohexanol	13491-79-7
Ethyl butyrate	105-54-4
Linalool	78-70-6
Nonadecane	629-92-5
Dodecane	112-40-3
Decyl trifluoroacetate	333-88-0

*Classified as potentially hazardous.

20. Handwashing soap/liquid

Compounds	CAS#
Limonene*	138-86-3
Eucalyptol	470-82-6
Benzyl acetate	140-11-4
Linalool	78-70-6
beta-trans-Ocimene	3779-61-1
Methanol*	67-56-1
beta-Myrcene	123-35-3
Toluene*	108-88-3
Nonadecane	629-92-5
(Z)-7-tetradecene	41446-60-0
m-Cymene	535-77-3
Linalyl anthranilate	7149-26-0

*Classified as potentially hazardous.

21. Handwashing soap/liquid ^G

Compounds	CAS#
Limonene*	138-86-3
beta-Myrcene	123-35-3
alpha-Pinene	80-56-8
gamma-Terpinene	99-85-4
Linalool	78-70-6
Ethanol*	64-17-5
(R)-(+)- β -Citronellol	1117-61-9
beta-trans-Ocimene	3779-61-1
cis-3,7-Dimethyl-2,6-octadien-1-ol	106-25-2
Acetaldehyde*	75-07-0
beta-Phellandrene	555-10-2
1-Octanol*	111-87-5
3-Isopropenyl-5-methyl-1-cyclohexene	56816-08-1
Neryl acetate	141-12-8
beta-trans-Ocimene	3779-61-1
alpha-Phellandrene	99-83-2
Piperonal	120-57-0

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

22. Handwashing soap/liquid ^G

Compounds	CAS#
Limonene*	138-86-3
Camphene	79-92-5
Eucalyptol	470-82-6
Cyclofenchene	488-97-1
Benzyl alcohol*	100-51-6
beta-Myrcene	123-35-3
alpha-Pinene	80-56-8
Isomenthone	491-07-6
6-Methyl-5-hepten-2-one	110-93-0
(-)-Isopulegol	89-79-2
3-Carene*	13466-78-9
Benzaldehyde*	100-52-7
Acetaldehyde*	75-07-0
Linalool	78-70-6
1-Octanol*	111-87-5
Caryophyllene	87-44-5
Sabinene	3387-41-5
DL-menthyl acetate	16409-45-3
2-Methylfuran	534-22-5
Isoamyl alcohol	123-51-3

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

23. Handwashing soap/liquid ^G

Compounds	CAS#
Ethanol*	64-17-5
Pentane*	109-66-0
alpha-Pinene	80-56-8
Limonene*	138-86-3
beta-Pinene	127-91-3
Eucalyptol	470-82-6
Linalool	78-70-6
beta-Myrcene	123-35-3
Linalyl anthranilate	7149-26-0
Camphene	79-92-5
trans-2-Pentene	646-04-8
Butane*	106-97-8
3-Methylhexane*	589-34-4
Acetaldehyde*	75-07-0
1-Heptene	592-76-7
2,3,4-Trimethylhexane	921-47-1
1-Octene	111-66-0
Terpinolene	586-62-9
beta-trans-Ocimene	3779-61-1
Caryophyllene	87-44-5

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms.

24. Handwashing soap/liquid ^G

Compounds	CAS#
Eucalyptol	470-82-6
Limonene*	138-86-3
alpha-Pinene	80-56-8
o-Cymene	527-84-4
3-Carene*	13466-78-9
beta-Pinene	127-91-3
alpha-Phellandrene	99-83-2
beta-Myrcene	123-35-3
beta-Phellandrene	555-10-2
gamma-Terpinene	99-85-4
Pentane*	109-66-0
Camphene	79-92-5
(Z)-beta-ocimene	3338-55-4

*Classified as potentially hazardous.

^G Products with the claim of being "Green" or related terms

25. Handwashing soap/liquid

Compounds	CAS#
alpha-Pinene	80-56-8
Ethanol*	64-17-5
Eucalyptol	470-82-6
Limonene*	138-86-3
(±)-Citronellal	106-23-0
Camphor	76-22-2
gamma-Terpinene	99-85-4
Benzyl acetate	140-11-4
o-Cymene	527-84-4
beta-Pinene	127-91-3
Pentane*	109-66-0
Heptane*	142-82-5
Octane*	111-65-9
2-Phenethyl acetate	103-45-7
Methyl phenylcarbinyl acetate	93-92-5
Camphene	79-92-5
3-Carene*	13466-78-9
alpha-Terpinene	99-86-5
Butane*	106-97-8
Hexane*	110-54-3

*Classified as potentially hazardous.

26. Handwashing soap/liquid

Compounds	CAS#
Limonene*	138-86-3
alpha-Pinene	80-56-8
Linalool	78-70-6
Ethanol*	64-17-5
Camphor	76-22-2
beta-Pinene	127-91-3
3-Carene*	13466-78-9
3-Methyl-2-butenic acid, 2-pentyl ester	150462-84-3
Propanoic acid, 2-methyl-, 2-methylbutyl ester	2445-69-4
Camphene	79-92-5
Isobutyl isobutyrate	97-85-8
Methacrolein	78-85-3
2-Butoxyethanol*	111-76-2
Amyl senecioate	56922-72-6
2(10)-Pinen-3-one	30460-92-5
beta-trans-Ocimene	3779-61-1
Butane*	106-97-8
(Z)-beta-ocimene	3338-55-4
2-Methyl-1-propene*	115-11-7

*Classified as potentially hazardous.

Supplementary Table 2: All emitted VOCs from all products

Compound	CAS #	Prevalence (# of Products)		
		Total (n=26)	Regular (n=13)	Green (n=13)
Limonene*	138-86-3	21	10	11
Ethanol*	64-17-5	17	7	10
alpha-Pinene	80-56-8	13	7	6
beta-Pinene	127-91-3	12	8	4
Acetaldehyde*	75-07-0	11	4	7
Eucalyptol	470-82-6	11	4	7
gamma-Terpinene	99-85-4	11	5	6
beta-Myrcene	123-35-3	10	1	9
beta-trans-Ocimene	3779-61-1	10	3	7
Camphene	79-92-5	10	5	5
3-Carene*	13466-78-9	8	4	4
beta-Phellandrene	555-10-2	8	5	3
Linalool	78-70-6	8	4	4
alpha-Phellandrene	99-83-2	7	3	4
Methanol*	67-56-1	7	3	4
6-Methyl-5-hepten-2-one	110-93-0	6	4	2
o-Cymene	527-84-4	6	4	2
Terpinolene	586-62-9	6	3	3
Acetone*	67-64-1	5	1	4
Butane*	106-97-8	5	4	1
4-tert-Butylcyclohexyl acetate	32210-23-4	4	3	1
alpha-Terpinene	99-86-5	4	4	0
Octanal	124-13-0	4	1	3
Sabinene	3387-41-5	4	1	3
(Z)-7-tetradecene	41446-60-0	3	2	1
(Z)-beta-ocimene	3338-55-4	3	2	1
1-Octanol*	111-87-5	3	0	3
alpha-Thujene	2867-05-2	3	2	1
Benzyl acetate	140-11-4	3	3	0
Camphor	76-22-2	3	2	1
Cyclohexane*	110-82-7	3	2	1
Dodecane	112-40-3	3	1	2
Ethyl acetate*	141-78-6	3	2	1
Pentane*	109-66-0	3	1	2
Terpinyl acetate	80-26-2	3	2	1
(E)-citral*	141-27-5	2	1	1

2,7-Dimethyl-2,7-octanediol	19781-07-8	2	1	1
2-Butoxyethanol	111-76-2	2	1	1
2-Methyl-2-propanol*	75-65-0	2	2	0
2-Nonenenitrile	29127-83-1	2	1	1
2-tert-Butylcyclohexanol	13491-79-7	2	1	1
3-Methoxy-3-methylbutanol	56539-66-3	2	1	1
Acetaldehyde diethyl acetal*	105-57-7	2	1	1
Allyl hexanoate	123-68-2	2	1	1
alpha-Fenchene	471-84-1	2	1	1
beta-Citral*	106-26-3	2	1	1
Butanone*	78-93-3	2	1	1
Caryophyllene	87-44-5	2	0	2
Decane	124-18-5	2	2	0
Dihydromyrcenol	18479-58-8	2	2	0
Ethyl butyrate	105-54-4	2	2	0
Ethyl isobutyrate	97-62-1	2	2	0
Hexyl acetate	142-92-7	2	1	1
Isopropyl alcohol*	67-63-0	2	1	1
Linalyl anthranilate	7149-26-0	2	1	1
Nonadecane	629-92-5	2	2	0
(-)-Isopulegol	89-79-2	1	0	1
(±)-Citronellal	106-23-0	1	1	0
(E)-2,5-Dimethyl-1,6-octadiene	68702-25-0	1	1	0
(E)-3-Tetradecene	41446-68-8	1	0	1
(E)-5-Tetradecene	41446-66-6	1	0	1
(R)-(+)-β-Citronellol	1117-61-9	1	0	1
(Z)-rose oxide	16409-43-1	1	1	0
1-(1,2-Dimethyl-cyclopent-2-enyl)-ethanone	70987-82-5	1	1	0
1,1-dichloroethylene*	75-35-4	1	1	0
1,3,8-p-Menthatriene	21195-59-5	1	1	0
1,3-Dimethyl-2-(1-methylethyl)cyclopentene	61142-32-3	1	1	0
1,4-Cineole	470-67-7	1	0	1
1-[2-(Allyloxy)-1-methylethoxy]-2-propanol	55956-25-7	1	1	0
1-Decanol	112-30-1	1	0	1
1-Heptene	592-76-7	1	0	1
1-Isopropyl-2,3-dimethyl-1-cyclopentene	7712-73-4	1	1	0
1-Isopropyl-2-methyl-3-(1-methylethylidene)cyclopropane	24524-51-4	1	1	0

1-Isopropyl-4-methylbenzene	99-87-6	1	0	1
1-Methoxy-4-propylbenzene	104-45-0	1	0	1
1-Methyl-1,4-cyclohexadiene	4313-57-9	1	1	0
1-Octene	111-66-0	1	0	1
2(10)-Pinen-3-one	30460-92-5	1	1	0
2-(2-Hydroxypropoxy)-1-propanol	106-62-7	1	1	0
2-(6-Octynyl)-1,3-dioxolane	56741-65-2	1	1	0
2-(cis-4-methylcyclohexyl)-2-propanol	7322-63-6	1	0	1
2,2-Diethoxypropane	126-84-1	1	1	0
2,3,4-Trimethylhexane	921-47-1	1	0	1
2,3-Dimethylpentane	565-59-3	1	1	0
2,3-Epoxyhexanol	90528-63-5	1	1	0
2,4-Dimethyl-3-cyclohexenecarboxaldehyde	68039-49-6	1	1	0
2,4-Dimethylpentane*	108-08-7	1	1	0
2,7-Dimethyl-1,7-octadiene	59840-10-7	1	1	0
2-Bornene	464-17-5	1	1	0
2-chlorotoluene*	95-49-8	1	0	1
2-Methyl-1-propene*	115-11-7	1	1	0
2-Methylfuran	534-22-5	1	0	1
2-Phenethyl acetate	103-45-7	1	1	0
3,4-Dimethyl-3-cyclohexene-1-carboxaldehyde	18022-66-7	1	1	0
3-Buten-2-ol, 2-methyl-	115-18-4	1	0	1
3-Isopropenyl-5-methyl-1-cyclohexene	56816-08-1	1	0	1
3-Methyl-2-butenic acid, 2-pentyl ester	150462-84-3	1	1	0
3-Methylenecyclohexene	1888-90-0	1	1	0
3-Methylhexane*	589-34-4	1	0	1
5-Methylheptan-3-one*	541-85-5	1	1	0
6-Methyl-1,6-heptadiene	13643-06-6	1	1	0
Allyl alcohol*	107-18-6	1	1	0
Allyl heptanoate	142-19-8	1	0	1
Amyl senecioate	56922-72-6	1	1	0
Benzaldehyde*	100-52-7	1	0	1
Benzyl alcohol*	100-51-6	1	0	1
Bicyclo[4.1.0]hept-2-ene	2566-57-6	1	1	0
Butyraldehyde*	123-72-8	1	0	1
Carbon Tetrachloride*	56-23-5	1	1	0
Chloroform*	67-66-3	1	1	0

cis-3,7-Dimethyl-2,6-octadien-1-ol	106-25-2	1	0	1
Citral*	5392-40-5	1	0	1
Cyclofenchene	488-97-1	1	0	1
Cyclopropane, 1-methyl-2-(1-methylethyl)-3-(1-methylethylidene)-, cis-	24524-52-5	1	1	0
Decanal	112-31-2	1	0	1
Decyl trifluoroacetate	333-88-0	1	1	0
Diethyl phthalate	84-66-2	1	1	0
Diphenyl ether	101-84-8	1	1	0
Di-sec-butyl ether	6863-58-7	1	1	0
DL-menthyl acetate	16409-45-3	1	0	1
E-2-butene*	624-64-6	1	1	0
Ethyl 2-methylbutyrate	7452-79-1	1	1	0
Ethyl formate*	109-94-4	1	0	1
Geraniol	106-24-1	1	0	1
Heptan-4-one*	123-19-3	1	1	0
Heptane*	142-82-5	1	1	0
Hexane*	110-54-3	1	1	0
Hexyl propionate	2445-76-3	1	0	1
Isoamyl acetate*	123-92-2	1	1	0
Isoamyl alcohol	123-51-3	1	0	1
Isobutane*	75-28-5	1	1	0
Isobutyl isobutyrate	97-85-8	1	1	0
Isocitronellene	85006-04-8	1	1	0
Isomenthone	491-07-6	1	0	1
Isopropenyl formate	32978-00-0	1	1	0
Linalyl acetate	115-95-7	1	0	1
Linalyl formate	115-99-1	1	0	1
L-menthol	2216-51-5	1	0	1
m-Cymene	535-77-3	1	1	0
Menthone	10458-14-7	1	0	1
Methacrolein	78-85-3	1	1	0
Methyl (S)-2-methylbutanoate	53955-81-0	1	0	1
Methyl acetate*	79-20-9	1	0	1
Methyl butyrate	623-42-7	1	0	1
Methyl hexanoate	106-70-7	1	0	1
Methyl isobutyl ketone*	108-10-1	1	0	1
Methyl laurate	111-82-0	1	0	1
Methyl phenylcarbinyl acetate	93-92-5	1	1	0
Methyl propionate	554-12-1	1	0	1
Methyl valerate	624-24-8	1	0	1

Myrtanyl acetate	29021-36-1	1	1	0
N,N-dimethylacetamide*	127-19-5	1	1	0
N-Benzoyloxycarbonyl-dl-norleucine	15027-13-1	1	1	0
N-Chlorodimethylamine	1585-74-6	1	1	0
Neryl acetate	141-12-8	1	0	1
Octane*	111-65-9	1	1	0
Piperonal	120-57-0	1	0	1
Prenyl acetate	1191-16-8	1	1	0
Propane*	74-98-6	1	1	0
Propanoic acid, 2-methyl-, 2-methylbutyl ester	2445-69-4	1	1	0
Propylene glycol butyl ether*	5131-66-8	1	1	0
Styrene*	100-42-5	1	1	0
Tetracarbonylnickel*	13463-39-3	1	1	0
Tetrahydrolinalool	57706-88-4	1	1	0
Toluene*	108-88-3	1	1	0
trans-2-Pentene	646-04-8	1	0	1
trans-3-Isopropyl-6-methylcyclohexene	1124-26-1	1	1	0
Tricyclene	508-32-7	1	1	0
Tridecane	629-50-5	1	0	1
Trivertal	27939-60-2	1	1	0
Undecane	1120-21-4	1	0	1
Verdyl acetate	5413-60-5	1	1	0

*Compound classified as potentially hazardous