Volatile Emissions from Common Consumer Products

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Abstract

Consumer products emit a range of volatile organic compounds (VOCs) that can affect air quality and health. Risk reduction is hindered because of lack of information about specific product emissions. This study investigates and compares VOCs emitted from 37 common products (air fresheners, laundry products, cleaners, and personal care products), including those with certifications and claims of green and organic. It extends a prior study of 25 consumer products by adding 12 more products, including fragrance-free versions of fragranced products, representing the first such comparison in the scientific literature. This study found 156 different VOCs emitted from the 37 products, with an average of 15 VOCs per product. Of these 156 VOCs, 42 VOCs are classified as toxic or hazardous under U.S. federal laws, and each product emitted at least one of these chemicals. Emissions of carcinogenic hazardous air pollutants (HAPs) from green fragranced products were not significantly different from regular fragranced products. The most common chemicals in fragranced products were terpenes, which were not in fragrance-free versions. Of the volatile ingredients emitted, fewer than 3% were disclosed on any product label or material safety data sheet (MSDS). Because health effects depend on many factors, not only individual ingredients, this study makes no claims regarding possible risks. However, knowledge of product composition can be an important step to understand, assess, and reduce potential exposures and effects.

Keywords: Consumer Products, VOC Emissions, Fragrance, Fragrance-Free, Green

Background

In the U.S. and other countries, consumer products represent a major source of human exposure to VOCs (e.g., Wallace, 2001; Edwards et al., 2006) and indoor air pollutants (Weisel 2002; Geiss et al., 2011; Sarigiannis et al., 2011; Wallace, 1991). Fragranced products, for instance, emit terpenes such as limonene and alpha-pinene (Steinemann et al. 2011; Wallace et al., 1991), which dominate VOC concentrations found indoors (Maisey, et al. 2013; Geiss et al. 2011). Terpenes react with ozone to generate a range of secondary pollutants including formaldehyde, acetaldehyde, secondary organic aerosols, and ultrafine particles (Rossignol et al., 2013; Nazaroff and Weschler, 2004; Singer et al., 2006). Consumer product VOCs from indoor sources can also migrate outdoors, affecting ambient air quality (e.g., Steinemann et al. 2013; Chen and Luo, 2012).

Efforts to reduce VOC exposures from consumer products have been impaired by lack of product ingredient information. Manufacturers are not required to disclose all ingredients in a product, or any ingredients in a chemical mixture called fragrance (Steinemann 2009). Given lack of information, consumers may turn to products with claims such as green, natural, or organic, but those claims are largely unregulated and untested (Scruggs and Ortolano, 2011; Dahl, 2010). Consumers also may also turn to popular product evaluation guides (e.g., Good Guide, 2014; EWG, 2014a, b), but these guides often rely solely on disclosed information for their assessments, without analyzing product contents. Similarly, risk and exposure assessments often depend on accurate and complete

ingredient information, but product databases typically contain only listed ingredients (Mitchell et al., 2013; Goldsmith et al. 2014).

This article reports and compares volatile emissions among a range of consumer product types (air fresheners, laundry products, cleaners, and personal care products) and different product categories (fragranced, fragrance-free, green, and regular). It incorporates and builds upon the work of Steinemann et al. (2011), which analyzed 25 fragranced consumer products, by including an additional set of products (12 more) to represent a greater diversity of product types and categories, including 6 products with certifications or claims of green and organic, and 6 fragrance-free products (a new category), which offers 4 matched pairs of the same brands of fragranced and fragrance-free laundry products. In addition, this article identifies and compares VOCs classified as toxic or hazardous under U.S. federal laws among these four product categories, and examines differences between VOCs emitted and ingredients disclosed to the public.

Approach

Gas chromatography/mass spectrometry (GC/MS) headspace analysis was used to identify VOCs emitted from 37 products, representing four types and four categories (Table 1): types are 9 air fresheners (sprays, gels, solids, oils, and disks), 11 laundry products (detergents, dryer sheets, and fabric softeners), 7 cleaners (household and industrial cleaning products, disinfectants, and dish detergent), and 10 personal care products (soaps, hand sanitizers, lotions, deodorants, shampoo, and baby shampoo); categories are 7 green, 20 regular, 31 fragranced, and 6 fragrance-free.

"Green" products are defined, for this study, as those that make a claim such as "green," "organic," "non-toxic," "environmentally friendly," "essential oils," or "natural" on their product label or MSDS. The analysis of green products included those with claims of "green certified" (e.g., Green Seal, 2014) or ingredients that are "certified organic." "Regular" products are those other than in the "green" category.

"Fragranced" products are defined, for this study, as those with an added or intentional fragrance or scent. A "fragrance" is typically a mixture of several dozen to several hundred chemicals, with an estimated 80%-90% synthetically derived (Somogyi, et al., 1998). "Fragrance-free" products are defined as those claiming to be without a fragrance.

Products were selected that are commonly used in the U.S. and other countries by individuals, households, industries (e.g., workplaces, hotels, restaurants, stores), institutions (e.g., schools, hospitals, homeless shelters), and in other environments (e.g., apartment buildings, parks, child care and elder care facilities, government buildings, airplanes, and public transportation).

A regulatory analysis determined VOCs classified as toxic or hazardous under one or more U.S. federal laws. The objective was to identify compounds that are currently regulated, based on toxicity concerns, and thus could warrant attention and further study. This analysis does not imply that these compounds are the only ingredients with potential toxicities, that they are toxic as found in the products, or that individual chemicals alone determine overall product toxicity, which depends on other factors such as concentrations and interactions among chemicals in mixtures.

In prior studies that investigated VOC emissions from fragranced consumer products (e.g., Wallace et al., 1991; Cooper et al., 1992; Steinemann et al., 2011; Jo et al., 2008), limonene was the most commonly found VOC, along with β-pinene, α-pinene, ethanol, acetone, and acetaldehyde. This present study differs from previous work that analyzed fragranced consumer products but that looked at only certain VOCs rather than the full suite (e.g., Dodson et al., 2012; Rastogi et al., 2001), that analyzed one product type or category (e.g., Jo et al., 2008), that did not distinguish whether products were fragranced (Kwon et al. 2007; Sack et al., 1992), that analyzed fragranced but not fragrance-free versions (Steinemann et al. 2011) or green products (Wallace et al., 1991, Cooper et al. 1992), or that composited samples and consolidated results among products (e.g., Dodson et al., 2012) thus limiting knowledge of individual product emissions and comparisons with ingredients disclosed.

Ingredients in consumer products, and in fragrance formulations, are exempt from full disclosure to the public (see regulatory details in Steinemann, 2009; Steinemann and Walsh, 2007). For laundry products, cleaning supplies, and air fresheners, regulated under the U.S. Consumer Product Safety Act (CPSA), labels do not need to list all ingredients, or the presence of a fragrance in the product. For personal care products, regulated under the U.S. Federal Food, Drug, and Cosmetic Act (FFDCA), labels need to list ingredients, except the general term "fragrance" may be used instead of listing the individual ingredients in the fragrance. For all products, material safety data sheets, under the U.S. Occupational Safety and Health Act, do not need to list all ingredients. Fragrance ingredients are exempt from full disclosure in any product, not only in the U.S. but also internationally.

Analysis and Results

Consumer products were analyzed using headspace GC/MS, following U.S. EPA Compendium Method TO-15 (EPA, 1999). For each product, the top 20 peaks from the sample chromatogram were identified, as detailed in Steinemann et al. (2011), using mass spectral library matches. This article reports only VOCs with headspace concentrations of greater than 100 $\mu g/m^3$, to ensure they are definitive ingredients emitted from the products.

This study generated voluminous amounts of data, which can be analyzed and displayed in many different ways. This article will focus on the key dimensions and salient results. Complete data on VOCs identified and headspace concentrations, including designations of product types and categories, are provided as Supplementary Table 1 (available on-line).[1.]

VOCs emitted. A summary of VOCs emitted according to product category is provided in Table 2. The term "occurrences" refers to the number of individual VOC peaks detected among the products; thus, each occurrence represents an ingredient in a product. The term "unique" refers to the number of unique VOCs; thus, each unique VOC represents a specific chemical ingredient found in one or more products. Table 3 lists compounds in at least 33% of all products, and Tables 4-7 list compounds in at least 33% of the products in their respective categories.

All VOCs. Collectively, a total of 559 VOC occurrences were detected across the 37 consumer products, representing 156 unique VOCs. Headspace concentrations ranged

[1] In Supplementary Table 1, products #1-#25 represent the set from Steinemann et al. (2011) and #26-#37 the additional 12 products for this study.

from the minimum threshold value of 100 μg/m^3 to a maximum value of over 2,600,000 μg/m^3.

Most prevalent. Among all 37 products, the most prevalent VOCs (in at least 50% of the products) were ethanol, d-limonene, β-pinene, and α-pinene (Table 3). (This article will use "most prevalent" to refer to "in at least 50% of the products.")

Most prevalent among categories. In fragranced products, the most prevalent VOCs were d-limonene, β-pinene, α-pinene, ethanol, and acetone (Table 4), and the latter two were also found in fragrance-free products. In fragrance-free products, the most prevalent VOCs were ethanol, acetaldehyde, methanol, and undecane (Table 5), and all were also found in fragranced products. Comparing the most prevalent compounds in green and regular products, four out of five are the same (d-limonene, β-pinene, ethanol, and α-pinene) (Tables 6 and 7).

Regulatory classifications. Of the 156 unique VOCs emitted from the 37 products, 42 unique VOCs are classified as toxic or hazardous under U.S. federal laws (Tables 2 and 8). Each product emitted at least one of these potentially hazardous VOCs. About half of the products (19) emitted one or more carcinogenic hazardous air pollutants (1,4-dioxane, formaldehyde, acetaldehyde, and methylene chloride), which have no safe threshold of exposure, according to the U.S. Environmental Protection Agency (EPA, 1994, 2005, 2007).

Most prevalent classified as toxic or hazardous. Among the most prevalent VOCs in the products (found in at least half of the products), 80% are classified as toxic or hazardous under U.S. federal laws (Tables 3 and 8): ethanol, d-limonene, α-pinene, and acetone. In

each of the four product categories, among the most prevalent VOCs (in more than half the products), between 75%–80% are classified as toxic or hazardous: acetaldehyde, ethanol, d-limonene, α-pinene, acetone, and methanol. (See Tables 4-8; Supplementary Tables 2-5.)

Green products. Of the most prevalent VOCs, 80% are the same between green and regular products, and of the most prevalent classified as toxic or hazardous, 75% are the same between green and regular products. (See Tables 4-8; Supplementary Tables 2-5.) Of the 17 green products, 7 emitted at least one carcinogenic HAP. Comparing the 17 green and 20 regular products, as well as the 15 green fragranced products and 16 regular fragranced products, no statistically significant difference (α=0.05) was found between the relative number of products in each category that contained carcinogenic HAPs.

Fragranced and fragrance-free versions. This study investigated four specific brands of regular laundry products with both fragranced and fragrance-free versions (see Tables 9a-d). The primary difference between the fragranced and fragrance-free versions is the presence of terpenes (such as d-limonene, β-pinene, α-pinene) in the fragranced versions but not the fragrance-free versions.

Disclosure on labels and MSDSs. Among the 559 VOC occurrences, only 21 were listed on any product label or MSDS, 7 of which were repeated listings between labels and MSDSs, so 14 ingredients total were disclosed.[2] Thus, fewer than 1% of all ingredients in the products were listed on any product label, fewer than 2% on any product MSDS, and fewer than 3% in either location. Moreover, considering the 230

[2] Specifically, on product labels, 5 VOCs represented a total of 8 occurrences (ethanol, 3; isopropyl alcohol, 2; d-limonene, 1; acetone, 1; propane, 1) and on product MSDSs, 6 VOCs represented a total of 13 occurrences (ethanol, 8; isopropyl alcohol, 1; d-limonene, 1; acetone, 1; propane, 1; 2-butyoxyethanol, 1).

VOCs classified as toxic or hazardous, fewer than 6% of these ingredients were disclosed on either the label or MSDS.[3]

In summary, 10 products listed no ingredients on the product label, and 8 products listed no ingredients on the MSDS.[4] In addition, 21 of the 31 fragranced products did not disclose the presence of a "fragrance" on either the label or the MSDS, or both.[5] However, each product appears to be in compliance with their respective laws for disclosing (or not disclosing) ingredients. (Steinemann 2009 provides a detailed analysis of relevant laws.)

Limitations. This study did not seek to assess and makes no claims regarding potential health risks from products. In addition, the analysis focused on the identities of individual chemicals, yet potential product toxicity depends on other factors, such as mixtures of chemicals and concentrations. The GC/MS headspace analysis measured primary VOC emissions, directly from each product, which did not capture the generation of secondary pollutants.

[3] This article does not provide specific wording from product labels and MSDSs because it could lead to the identification of product brands.

[4] For the 28 products regulated by the CPSC: On the labels, 10 listed no ingredients, and on the MSDSs, 5 listed no ingredients. For the 9 products regulated by the FDA: On the labels, all 9 listed ingredients, and on the MSDS, 3 listed no ingredients.

[5] These 31 products were determined to be fragranced because of product advertising (e.g., "original scent") or disclosure of a fragrance. For the 22 fragranced products regulated by the CPSA, 15 did not disclose a fragrance on the label, 12 did not disclose a fragrance on a MSDS, and 7 products did not disclose a fragrance on either. For the 9 fragranced products regulated by the FDA, all 9 disclosed a fragrance on the label, but 8 did not disclose a fragrance on the MSDS.

Conclusions and Discussion

This study provides striking findings concerning the range of VOCs emitted by common consumer products. Consumer products are a primary source of human exposure to VOCs, including hazardous air pollutants. However, consumers lack information about actual and complete product ingredients and emissions, given that most ingredients (over 97% in this study) are not disclosed, and most potentially hazardous ingredients (over 94% in this study) are also not disclosed.

Given lack of ingredient information, consumers may seek out products with claims and certifications of green or organic, in hopes to reduce potential risks. But well-intentioned efforts could be hindered, because product claims can be misleading or unsubstantiated. Even many product evaluation guides base their assessment solely on disclosed ingredients, reinforcing the problem of misinformation for consumers. Further, the disclosure of some chemicals, but not all chemicals, on product labels and MSDSs may lead consumers to presume that they are seeing all ingredients.

Future research directions and extensions include the following. A primary area is the analysis of potential health risks, whether through voluntary or involuntary exposures to products. Emission rates from each product could be measured in order to help estimate exposures and the contributions of individual products to overall air quality. This study focused on VOCs, but other types of product emissions can be analyzed, such as semi-volatile organic compounds and ultrafine particles. The analysis of chemicals could identify and explore differences between natural and synthetic compounds as used in

products and fragrance formulations. Consumer products used indoors, such as laundry supplies, can affect outdoor air quality, such as through dryer vent emissions, and effects of different products on air quality could be investigated. In sum, common consumer products represent a significant but largely unregulated and understudied source of human exposure to VOCs, and thus continued research could promote awareness and efforts among agencies, industries and the public to reduce health risks and improve air quality.

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Table 1
Products Tested by Type and Category

	Air Fresheners	Laundry Products	Cleaners	Personal Care Products
Fragranced	9 (8+1)	5 (4+1)	7 (4+3)	10 (9+1)
Fragrance Free	0	6 (0+6)	0	0
Green	6 (6+0)	2 (0+2)	4 (1+3)	5 (4+1)
Regular	3 (2+1)	9 (4+5)	3 (3+0)	5 (5+0)

Total number of products tested in each category; in parenthesis, first number refers to distribution of 25 products from Steinemann et al. (2011), second number to additional 12 products. Of the fragranced products, 15 are regular and 16 are green. Of the fragrance-free products, 2 are regular and 4 are green.

Table 2
VOCs by Product Category

Product Category	Number of Products	All VOCs	Toxic/Hazardous VOCs	Carcinogenic VOCs
All products	37	559 occurrences 156 unique	230 occurrences 42 unique	23 occurrences 4 unique
Fragranced	31	511 occurrences 144 unique	196 occurrences 35 unique	17 occurrences 4 unique
Fragrance Free	6	48 occurrences 31 unique	34 occurrences 20 unique	6 occurrences 2 unique
Green	17	279 occurrences 102 unique	111 occurrences 28 unique	8 occurrences 3 unique
Regular	20	280 occurrences 108 unique	119 unique 32 unique	15 occurrences 3 unique

Table 3
All Products (n=37): Common compounds

Compound	CAS #	Prevalence (# of Products)
ethanol	64-17-5	29
d-limonene	138-86-3	28
β-pinene	127-91-3	25
α-pinene	80-56-8	23
acetone	67-64-1	20
acetaldehyde*	75-07-0	15
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	14
carene isomer	e.g. 13466-78-9	13
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	13
benzyl acetate	140-11-4	12
methanol	67-56-1	12
α-terpinene	99-86-5	11
camphene	79-92-5	11
β-phellandrene	555-10-2	9
butane	106-97-8	9
ethyl butanoate	105-54-4	9
γ-terpinene	99-85-4	9
isopropyl alcohol	67-63-0	9

Legend for Tables 3-7:
"Common compounds" = found in >33% of products in category
bold = classified as toxic or hazardous under federal laws
* = classified as carcinogen by EPA (2007)

Table 4
Fragranced Products (n=31): Common compounds

Compound	CAS #	Prevalence (# of Products)
d-limonene	138-86-3	28
β-pinene	127-91-3	25
α-pinene	80-56-8	23
ethanol	64-17-5	23
acetone	67-64-1	18
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	14
carene isomer	e.g. 13466-78-9	13
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	13
benzyl acetate	140-11-4	12
acetaldehyde*	75-07-0	11
α-terpinene	99-86-5	11
camphene	79-92-5	11

Table 5
Fragrance-Free Products (n=6): Common compounds

Compound	CAS #	Prevalence (# of products)
ethanol	64-17-5	6
acetaldehyde*	75-07-0	4
methanol	67-56-1	4
undecane	1120-21-4	3
1,4-dioxane*	123-91-1	2
2-methoxy propane	598-53-8	2
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	2
acetone	67-64-1	2

Table 6
Green Products (n=17): Common compounds

Compound	CAS #	Prevalence (# of products)
d-limonene	138-86-3	14
acetone	67-64-1	13
β-pinene	127-91-3	12
ethanol	64-17-5	11
α-pinene	80-56-8	11
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	8
carene isomer	e.g. 13466-78-9	8
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	8
benzyl acetate	140-11-4	7
butane	106-97-8	7
camphor	76-22-2	7
methanol	67-56-1	7
camphene	79-92-5	6
ethyl butanoate	105-54-4	6
ɣ-terpinene	99-85-4	6
isopropyl alcohol	67-63-0	6

Table 7
Regular Products (n=20): Common compounds

Compound	CAS #	Prevalence (# of Products)
ethanol	64-17-5	18
d-limonene	138-86-3	14
β-pinene	127-91-3	13
α-pinene	80-56-8	12
acetaldehyde*	75-07-0	11
acetone	67-64-1	7
α-terpinene	99-86-5	7

Table 8
All Products (n=37): Compounds regulated as toxic or hazardous

Compound	CAS #	Prevalence (# of products)	CAA-TFS	CAA-HAP	CERCLA	CWA	EPCRA	FIFRA	OSH ACT	RCRA
ethanol	64-17-5	29						√	√	
d-limonene	138-86-3	28						√		
α-pinene	80-56-8	23						√		
acetone	67-64-1	20			√			√	√	√
acetaldehyde*	75-07-0	15	√	√	√	√	√		√	√
methanol	67-56-1	12		√	√		√	√	√	√
butane	106-97-8	9	√							
isopropyl alcohol	67-63-0	9					√	√	√	
camphor	76-22-2	8						√	√	
linalool	78-70-6	7						√		
1-butanol, 3-methyl-, acetate	123-92-2	6			√	√			√	
2-methyl-2-propanol	75-65-0	6					√	√	√	
1,4-dioxane*	123-91-1	5		√	√		√		√	√
2-butanone	78-93-3	5		√	√		√		√	√
carbonyl sulfide	463-58-1	5	√	√	√		√			
ethyl acetate	141-78-6	5			√			√	√	√
cyclohexane	110-82-7	3			√	√	√	√	√	
n,n-dimethyl acetamide	127-19-5	3							√	
pentane	109-66-0	3	√					√	√	
2-butoxy-ethanol	111-76-2	2						√	√	
5-methyl-3-heptanone	541-85-5	2							√	
chloromethane	74-87-3	2	√	√	√	√	√		√	√
cumene	98-82-8	2		√	√		√		√	√
formaldehyde*	50-00-0	2	√	√	√	√	√	√	√	√
propene, 2-methyl-	115-11-7	2	√							
1-propanol	71-23-8	1						√	√	
acetic acid, butyl ester	123-86-4	1			√	√			√	
benzaldehyde	100-52-7	1						√		
butanal	123-72-8	1					√			
carbon disulfide	75-15-0	1	√	√	√	√	√	√	√	√
chloroethane	75-00-3	1	√	√	√	√	√		√	
dimethyl ether	115-10-6	1	√							
e-2-butene	624-64-6	1	√							
ethyl ether	60-29-7	1	√		√				√	√
ethyl formate	109-94-4	1						√	√	
heptane	142-82-5	1							√	
hexane	110-54-3	1		√	√		√		√	
isobutane	75-28-5	1	√							
methyl acetate	79-20-9	1							√	
methylene chloride*	75-09-2	1		√	√	√	√	√	√	√
octane	111-65-9	1							√	
propane	74-98-6	1	√						√	

Legend for Table 8, and Supplementary Tables 2-5:
CAA-TFS: Clean Air Act—Toxic and Flammable Substances for Accidental Release Prevention
CAA-HAP: Clean Air Act—Hazardous Air Pollutant
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act—Hazardous Substance
CWA: Clean Water Act—Priority Pollutant
EPCRA: The Emergency Planning & Community Right to Know Act—Toxic Release Inventory Chemical
FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act—Registered Pesticide
OSH Act: Occupational Safety and Health Act—Air Contaminants
RCRA: Resource Conservation and Recovery Act—Hazardous Constituents
*Classified as probable carcinogen by EPA (2007)

Table 9(a)
Comparison of Fragranced and Fragrance-Free Versions of Regular Laundry Product Brand

Laundry Products (#1 and #29)

Compound	CAS #	Fragranced	Fragrance Free
2-butanone (methyl ethyl ketone)	78-93-3	x	x
ethanol	64-17-5	x	x
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	x	
6-methyl-5-hepten-2-one	110-93-0	x	
acetaldehyde*	75-07-0		x
α-fenchene	471-84-1	x	
α-phellandrene	99-83-2	x	
α-pinene	80-56-8	x	
α-terpinene	99-86-5	x	
α-terpinolene	586-62-9	x	
β-phellandrene	555-10-2	x	
β-pinene	127-91-3	x	
camphene	79-92-5	x	
d-limonene	138-86-3	x	
γ -terpinene	99-85-4	x	
isocineole	470-67-7	x	
n,n-dimethyl acetamide	127-19-5	x	
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	x	
tetrahydro-2,2-dimethyl-5-(1-methyl-1-propenyl) furan	7416-35-5	x	
undecane	1120-21-4		x

Legend for Tables 9(a)-9(d):
Bold=regulated as toxic or hazardous under federal laws
*=classified as a probable carcinogen by the EPA

Table 9(b)
Comparison of Fragranced and Fragrance-Free Versions of Regular Laundry Product Brand

Laundry Products (#2 and #26)

Compound	CAS #	Fragranced	Fragrance Free
1,4-dioxane*	123-91-1	x	x
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	x	x
dodecane	112-40-3	x	x
ethanol	64-17-5	x	x
undecane	1120-21-4	x	x
1,3-dioxan-5-ol	4740-78-7		x
1-methyl-3-(1-methylethyl)-cyclohexene	13828-31-4	x	
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	x	
2-butanone (methyl ethyl ketone)	78-93-3	x	
3,7-dimethyl-1,6-octadiene	10281-56-8	x	
acetaldehyde*	75-07-0		x
α-pinene	80-56-8	x	
α-terpinene	99-86-5	x	
benzyl acetate	140-11-4	x	
β-pinene	127-91-3	x	
β-terpinene	99-84-3	x	
carene isomer	e.g. 13466-78-9	x	
cumene	98-82-8		x
d-limonene	138-86-3	x	
ethyl acetate	141-78-6	x	
ethyl ether	60-29-7		x
methanol	67-56-1		x

Table 9(c)
Comparison of Fragranced and Fragrance-Free Versions of Regular Laundry Product Brand

Laundry Products (#36 and #28)

Compound	CAS #	Fragranced	Fragrance Free
ethanol	64-17-5	x	x
acetaldehyde*	75-07-0	x	x
methanol	67-56-1	x	x
d-limonene	138-86-3	x	
2,7-dimethyl-2,7-octanediol	19781-07-8	x	
butane	106-97-8	x	
(z)-2-(3,3-dimethylcyclohexylidene)ethanol	26532-23-0	x	
acetone	67-64-1	x	
β-pinene	127-91-3	x	
carbon disulfide	75-15-0		x
carbonyl sulfide	463-58-1	x	
isopropyl alcohol	67-63-0	x	

Table 9(d)
Comparison of Fragranced and Fragrance-Free Versions of Regular Laundry Product Brand

Laundry Products (#4 and #27)

Compound	CAS #	Fragranced	Fragrance Free
2-methoxy propane	598-53-8	x	x
acetaldehyde*	75-07-0	x	x
chloromethane	74-87-3	x	x
diethoxy methane	462-95-3	x	x
ethanol	64-17-5	x	x
methoxy ethane	540-67-0	x	x
(z)-3,4-dimethyl-3-hexen-2-one	20685-45-4	x	
1,5-dimethyl-1,4-cyclohexadiene	4190-06-1	x	
1-methyltricyclo[2.2.1.0(2,6)]-heptane	4601-85-8	x	
2,4-dimethyl-1,3-cyclopentanedione	34598-80-6	x	
2-methyl-2-propanol (t-butyl alcohol)	75-65-0		x
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	x	
α-pinene	80-56-8	x	
α-terpinene	99-86-5	x	
α-terpinolene	586-62-9	x	
benzyl acetate	140-11-4	x	
β-pinene	127-91-3	x	
chloroethane	75-00-3		x
d-limonene	138-86-3	x	
ethyl formate	109-94-4		x
ɣ -terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	x	
isocineole	470-67-7	x	
linalool	78-70-6	x	

Supplementary Tables

Supplementary Table 1

VOCs Emissions from 37 Products

(Headspace Concentrations > 100 µg/m3)
Designation: F=fragranced; FF= fragrance-free; G=green; R=regular

1. Laundry product (F, R)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	40,853
isocineole	470-67-7	10,218
α-terpinolene	586-62-9	2,446
α-terpinene	99-86-5	2,063
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	1,949
ethanol	64-17-5	1,329
ɣ-terpinene	99-85-4	1,236
β-pinene	127-91-3	1,080
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	920
α-pinene	80-56-8	836
2-butanone (methyl ethyl ketone)	78-93-3	713
camphene	79-92-5	669
tetrahydro-2,2-dimethyl-5-(1-methyl-1-propenyl) furan	7416-35-5	623
α-phellandrene	99-83-2	584
n,n-dimethyl acetamide	127-19-5	525
6-methyl-5-hepten-2-one	110-93-0	519
β-phellandrene	555-10-2	221
α-fenchene	471-84-1	129
	Total Conc. (µg/m³)	66,913

2. Laundry product (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	932,430
d-limonene	138-86-3	32,988
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	3,988
1,4-dioxane	123-91-1	2,228
3,7-dimethyl-1,6-octadiene	10281-56-8	2,024
ethyl acetate	141-78-6	1,770
α-pinene	80-56-8	1,619
β-pinene	127-91-3	1,107
2-butanone (methyl ethyl ketone)	78-93-3	1,075
1-methyl-3-(1-methylethyl)-cyclohexene	13828-31-4	534
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	467
undecane	1120-21-4	324
β-terpinene	99-84-3	311
benzyl acetate	140-11-4	184
dodecane	112-40-3	182
α-terpinene	99-86-5	150
carene isomer	e.g. 13466-78-9	108
	Total Conc. (µg/m³)	981,489

3. Laundry product (F, R)

Compound	CAS #	Conc. (µg/m³)
linalool	78-70-6	2,721
ethanol	64-17-5	2,534
benzyl acetate	140-11-4	1,498
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	1,434
carene isomer	e.g. 13466-78-9	962
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	833
d-limonene	138-86-3	682
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	662
2,7-dimethyl-2,7-octanediol	19781-07-8	542
α-pinene	80-56-8	535
trans-rose oxide	876-18-6	475
eucalyptol (1,8-cineole)	470-82-6	420
benzyl alcohol, α-methyl-, acetate (α-phenylethyl acetate)	93-92-5	394
β-pinene	127-91-3	353
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	307
unknown		249
methyl benzoate	93-58-3	208
acetone	67-64-1	148
decanal	112-31-2	124
	Total Conc. (µg/m³)	15,081

4. Laundry product (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	810,906
d-limonene	138-86-3	74,447
methoxy ethane	540-67-0	7,535
α-pinene	80-56-8	6,918
benzyl acetate	140-11-4	3,642
isocineole	470-67-7	3,640
β-pinene	127-91-3	2,910
2-methoxy propane	598-53-8	2,702
linalool	78-70-6	2,630
(z)-3,4-dimethyl-3-hexen-2-one	20685-45-4	2,484
chloromethane	74-87-3	2,324
ɣ-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 or 19781-07-8	1,968
acetaldehyde	75-07-0	1,806
2,4-dimethyl-1,3-cyclopentanedione	34598-80-6	1,491
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	1,453
α-terpinolene	586-62-9	1,128
diethoxy methane	462-95-3	999
1,5-dimethyl-1,4-cyclohexadiene	4190-06-1	587
1-methyltricyclo[2.2.1.0(2,6)]-heptane	4601-85-8	535
α-terpinene	99-86-5	398
	Total Conc. (µg/m³)	930,503

5. Personal care product (F, R)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	36,007
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	9,455
ethanol	64-17-5	9,000
(z)-3,4-dimethyl-3-hexen-2-one	20685-45-4	4,219
α-pinene	80-56-8	4,203
β-pinene	127-91-3	3,324
ɣ-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	3,244
isocineole	470-67-7	3,153
2,4-dimethyl-1,3-cyclopentanedione	34598-80-6	2,521
camphor	76-22-2	2,462
linalool	78-70-6	2,331
benzyl acetate	140-11-4	1,927
methanol	67-56-1	1,615
camphene	79-92-5	1,582
α-terpinolene	586-62-9	1,006
acetone	67-64-1	999
β-terpinene	99-84-3	704
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	556
α-terpinene	99-86-5	528
carene isomer	e.g. 13466-78-9	456
	Total Conc. (µg/m³)	89,292

6. Personal care product (F, G)

Compound	CAS #	Conc. (µg/m³)
α-pinene	80-56-8	10,886
ethanol	64-17-5	3,118
eucalyptol (1,8-cineole)	470-82-6	2,838
d-limonene	138-86-3	1,944
citronella (3,7-dimethyl-6-octenal)	106-23-0	942
camphor	76-22-2	632
γ-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	622
benzyl acetate	140-11-4	565
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	469
β-pinene	127-91-3	388
pentane	109-66-0	372
heptane	142-82-5	366
octane	111-65-9	299
acetic acid, 2-phenylethyl ester	103-45-7	267
benzyl alcohol, α-methyl-, acetate (α-phenylethyl acetate)	93-92-5	255
camphene	79-92-5	238
carene isomer	e.g. 13466-78-9	202
α-terpinene	99-86-5	149
butane	106-97-8	141
hexane	110-54-3	134
	Total Conc. (µg/m³)	24,827

7. Personal care product (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	353,689
α-pinene	80-56-8	4,851
d-limonene	138-86-3	2,335
β-pinene	127-91-3	2,139
ethyl acetate	141-78-6	1,798
camphene	79-92-5	1,046
1,1-diethoxy-ethane	105-57-7	608
acetaldehyde	75-07-0	501
α-fenchene	471-84-1	351
1-methyl-1,4-cyclohexadiene	4313-57-9	201
cyclohexane	110-82-7	159
2-butanone (methyl ethyl ketone)	78-93-3	157
tricyclene (tent.)	508-32-7	151
β-phellandrene	555-10-2	125
	Total Conc. (µg/m³)	368,111

8. Cleaner (F, R)

Compound	CAS #	Conc. (μg/m³)
ethanol	64-17-5	742,850
3-methoxy-3-methylbutanol	56539-66-3	3,914
d-limonene	138-86-3	3,113
ethyl acetate	141-78-6	1,018
cumene	98-82-8	793
α-pinene	80-56-8	306
β-pinene	127-91-3	193
α-terpinene	99-86-5	110
	Total Conc. (μg/m³)	752,297

9. Personal care product (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	7,721
isopropyl alcohol	67-63-0	2,131
3-hexen-1-ol, acetate, (z)-	3681-71-8	1,975
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1,849
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	1,291
eucalyptol (1,8-cineole)	470-82-6	739
ethyl butanoate	105-54-4	665
acetic acid, butyl ester	123-86-4	457
2-methyl-2,4-dimethoxybutane	39836-89-0	389
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	199
formaldehyde	50-00-0	199
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	156
hexanoic acid, ethyl ester	123-66-0	150
acetaldehyde	75-07-0	119
acetone	67-64-1	111
carene isomer	e.g. 13466-78-9	105
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	104
	Total Conc. (µg/m³)	18,360

10. Personal care product (F, R)

Compound	CAS #	Conc. (µg/m³)
2,2,4,4,6,8,8-heptamethylnonane	4390-43-9	1,843
methanol	67-56-1	1,101
unknown alkanes		795
acetaldehyde	75-07-0	684
n,n-dimethyl acetamide	127-19-5	608
2,2,3,3,5,6,6-heptamethylheptane	7225-67-4	420
benzyl acetate	140-11-4	367
unknown alkane		356
d-limonene	138-86-3	354
formaldehyde	50-00-0	316
2,6,10-trimethyldodecane	3891-98-3	219
ethyl butanoate	105-54-4	199
unknown alkane		186
3-methoxy-3-methylbutanol	56539-66-3	163
unknown alkane		127
ethanol	64-17-5	114
4,4-dimethylcyclooctene		113
	Total Conc. (µg/m³)	7,965

11. Personal care product (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	72,867
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	47,347
unknown alkane		6,141
β-pinene	127-91-3	5,555
ethyl butanoate	105-54-4	3,666
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	3,653
allyl heptanoate	142-19-8	3,118
benzyl acetate	140-11-4	1,898
α-pinene	80-56-8	1,863
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1,781
methanol	67-56-1	1,278
1-butanol, 3-methyl-, acetate	123-92-2	1,221
4-tert-butylcyclohexyl acetate	32210-23-4	1,121
2-hexenal	6728-26-3	932
1,4-dioxane	123-91-1	814
ɣ-terpinene	99-85-4	636
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	569
unknown alkane		353
	Total Conc. (µg/m³)	154,813

12. Personal care product (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	47,970
ethyl butanoate	105-54-4	4,700
benzyl acetate	140-11-4	2,813
β-pinene	127-91-3	1,606
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1,444
ethanol	64-17-5	1,422
allyl heptanoate	142-19-8	978
isopropyl alcohol	67-63-0	952
α-pinene	80-56-8	654
methylene chloride	75-09-2	474
γ-terpinene	99-85-4	380
2,6-dimethyl-2-heptanol	13254-34-7	332
1,4-dioxane	123-91-1	293
carene isomer	e.g. 13466-78-9	273
cis-ocimene	3338-55-4	201
carene isomer	e.g. 13466-78-9	109
	Total Conc. (µg/m³)	64,601

13. Cleaner (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	16,508
α-pinene	80-56-8	1,322
β-pinene	127-91-3	953
ethyl acetate	141-78-6	492
d-limonene	138-86-3	343
cyclohexane	110-82-7	110
	Total Conc. (µg/m³)	19,728

14. Air freshener (F, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	1,582,010
d-limonene	138-86-3	66,924
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	40,802
β-pinene	127-91-3	30,377
propanoic acid, 2-methyl-, ethyl ester	97-62-1	17,675
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	15,739
5-methyl-3-heptanone	541-85-5	12,869
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	12,419
acetaldehyde	75-07-0	9,516
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	7,873
ɣ-terpinene	99-85-4	7,729
1-butanol, 3-methyl-, acetate	123-92-2	6,058
α-pinene	80-56-8	5,598
linalool	78-70-6	5,266
6-methyl-5-hepten-2-one	110-93-0	4,631
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	4,239
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	3,494
β-phellandrene	555-10-2	2,037
α-thujene	2867-05-2	997
	Total Conc. (µg/m³)	1,836,253

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15. Cleaner (F, R)

Compound	CAS #	Conc. (µg/m³)
1-butoxy-2-propanol	5131-66-8	164,199
eucalyptol (1,8-cineole)	470-82-6	3,614
n,n-dimethyl acetamide	127-19-5	2,785
4-tert-butylcyclohexyl acetate	32210-23-4	1,240
di-sec-butyl ether	6863-58-7	774
2,7-dimethyl-2,7-octanediol	19781-07-8	650
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	220
3-methoxy-3-methylbutanol	56539-66-3	214
4-heptanone	123-19-3	178
carene isomer	e.g. 13466-78-9	173
2,3-epoxyhexanol	90528-63-5	124
	Total Conc. (µg/m³)	174,171

16. Cleaner (F, G)

Compound	CAS #	Conc. (µg/m³)
eucalyptol (1,8-cineole)	470-82-6	108,321
d-limonene	138-86-3	48,033
isocineole	470-67-7	34,842
camphor	76-22-2	8,279
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	8,195
β-pinene	127-91-3	7,394
α-pinene	80-56-8	6,614
2-butanone (methyl ethyl ketone)	78-93-3	5,048
butanal	123-72-8	3,901
γ-terpinene	99-85-4	3,794
1-methoxy-4-propylbenzene	104-45-0	2,841
α-terpinolene	586-62-9	2,589
cyclohexane	110-82-7	1,794
2-butoxy-ethanol	111-76-2	1,431
α-phellandrene	99-83-2	927
acetone	67-64-1	774
tridecane	629-50-5	500
camphene	79-92-5	387
dodecane	112-40-3	354
	Total Conc. (µg/m³)	246,018

17. Personal care product (F, R)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	8,964
ɣ-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	5,144
β-pinene	127-91-3	1,997
α-pinene	80-56-8	1,005
3-octanol, 3,7-dimethyl	78-69-3	803
ethanol	64-17-5	678
1-methyl-3-(1-methylethyl)-cyclohexene	13828-31-4	374
3-isopropyl-5-methyl-hex-4-en-2-one	77142-85-9	366
acetone	67-64-1	333
carene isomer	e.g. 13466-78-9	279
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	277
α-terpinene	99-86-5	216
isocineole	470-67-7	198
propene, 2-methyl-	115-11-7	160
ethylmethyl pentane	609-26-7	112
	Total Conc. (µg/m³)	20,906

18. Air freshener (F, R)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	83,873
α-pinene	80-56-8	43,283
β-pinene	127-91-3	28,776
ethanol	64-17-5	20,726
ethyl butanoate	105-54-4	15,374
ethyl acetate	141-78-6	15,118
3-hexen-1-ol (leaf alcohol)	928-96-1	8,924
1-butanol, 3-methyl-, acetate	123-92-2	5,910
β-phellandrene	555-10-2	5,017
acetaldehyde	75-07-0	3,451
benzaldehyde	100-52-7	1,935
carene isomer	e.g. 13466-78-9	1,592
1-methyl-3-(1-methylethyl)-cyclohexene	13828-31-4	1,382
isopropyl alcohol	67-63-0	1,341
1-butanol, 2-methyl-, acetate	624-41-9	1,209
camphene	79-92-5	1,180
acetone	67-64-1	1,038
methyl butanoate	623-42-7	929
dimethyl ethyl cyclohexene	2228-98-0	446
α-thujene	2867-05-2	337
	Total Conc. (µg/m³)	241,841

19. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	11,297
3-methoxy-3-methylbutanol	56539-66-3	4,448
linalool	78-70-6	1,245
carene isomer	e.g. 13466-78-9	932
nonanal	124-19-6	726
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	644
2-methyl-2,4-dimethoxybutane	39836-89-0	583
benzyl alcohol, α-methyl-, acetate (α-phenylethyl acetate)	93-92-5	463
β-pinene	127-91-3	419
3-hexen-1-ol (leaf alcohol)	928-96-1	414
octanal	124-13-0	400
ethanol	64-17-5	318
ɣ-terpinene	99-85-4	170
decanal	112-31-2	161
acetone	67-64-1	160
cis-limonene oxide	4680-24-4	150
limonene oxide	1195-92-2	135
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	122
citronella (3,7-dimethyl-6-octenal)	106-23-0	105
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	103
	Total Conc. (µg/m³)	22,995

20. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
linalool	78-70-6	5,381
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	4,645
3-hexen-1-ol (leaf alcohol)	928-96-1	1,128
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	1,008
d-limonene	138-86-3	421
thujone	546-80-5	242
acetone	67-64-1	241
camphor	76-22-2	192
	Total Conc. (µg/m³)	13,258

21. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	21,920
4-tert-butylcyclohexyl acetate	32210-23-4	15,200
acetaldehyde	75-07-0	13,364
benzyl acetate	140-11-4	13,001
2,7-dimethyl-2,7-octanediol	19781-07-8	8,247
acetone	67-64-1	8,237
ethanol	64-17-5	3,429
carene isomer	e.g. 13466-78-9	2,112
citronellyl acetate	150-84-5	1,874
hexanal	66-25-1	1,411
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1,242
allyl heptanoate	142-19-8	1,189
1-methyl-4-(1-methylethyl)-cyclohexane	6069-98-3	1,170
ethyl butanoate	105-54-4	1,041
3-hexen-1-ol (leaf alcohol)	928-96-1	1,016
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	911
α-pinene	80-56-8	451
carene isomer	e.g. 13466-78-9	394
	Total Conc. (µg/m³)	96,209

22. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	135,284
1-butanol, 3-methyl-, acetate	123-92-2	24,347
hexyl acetate	142-92-7	23,005
benzyl acetate	140-11-4	11,875
4-(1,1-dimethylethyl)-cyclohexanol	98-52-2	9,227
acetone	67-64-1	8,324
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	7,676
β-pinene	127-91-3	6,359
ethyl butanoate	105-54-4	5,913
α-pinene	80-56-8	5,834
camphor	76-22-2	5,686
dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal isomer)	27939-60-2 or 67801-65-4	4,322
1-methoxy-4-methylbenzene	104-93-8	3,875
carene isomer	e.g. 13466-78-9	3,512
methyl benzoate	93-58-3	2,957
trans-rose oxide	876-18-6	2,361
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	2,103
β-phellandrene	555-10-2	1,536
camphene	79-92-5	1,007
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	842
	Total Conc. (µg/m³)	266,045

23. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
benzyl acetate	140-11-4	9,527
d-limonene	138-86-3	3,974
acetone	67-64-1	3,700
1-butanol, 3-methyl-, acetate	123-92-2	3,566
methanol	67-56-1	3,382
α-pinene	80-56-8	2,566
ethanol	64-17-5	1,872
acetaldehyde	75-07-0	1,728
ethyl butanoate	105-54-4	1,329
carene isomer	e.g. 13466-78-9	958
4-(1,1-dimethylethyl)cyclohexene	2228-98-0	493
methyl benzoate	93-58-3	423
unknown		373
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	356
5-methyl-3-heptanone	541-85-5	311
2-methylbenzyl acetate	17373-93-2	288
camphor	76-22-2	283
2,7-dimethyl-2,7-octanediol	19781-07-8	229
β-pinene	127-91-3	209
Carene isomer	e.g. 13466-78-9	129
	Total Conc. (µg/m³)	35,696

24. Air freshener (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	89,849
benzyl acetate	140-11-4	18,717
1-butanol, 3-methyl-, acetate	123-92-2	17,739
hexyl acetate	142-92-7	15,969
carene isomer	e.g. 13466-78-9	5,414
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	5,097
camphor	76-22-2	4,887
β-pinene	127-91-3	4,375
ethyl butanoate	105-54-4	3,683
dimethyl-3-cyclohexene-1-carboxaldehyde (triplal isomer)	27939-60-2 or 67801-65-4	3,551
α-pinene	80-56-8	3,382
methyl benzoate	93-58-3	2,400
1-methoxy-4-methylbenzene	104-93-8	2,350
acetone	67-64-1	2,241
trans-rose oxide	876-18-6	1,917
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (triplal 1)	68039-49-6	1,811
β-phellandrene	555-10-2	866
camphene	79-92-5	433
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	382
α-terpinene	99-86-5	352
	Total Conc. (µg/m³)	185,415

25. Personal care product (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	33,834
α-pinene	80-56-8	5,767
linalool	78-70-6	4,135
ethanol	64-17-5	3,247
camphor	76-22-2	2,149
β-pinene	127-91-3	1,659
carene isomer	e.g. 13466-78-9	1,645
3-methyl-2-butenoic acid, 2-pentyl ester	150462-84-3	1,433
propanoic acid, 2-methyl-, 2-methylbutyl ester	2445-69-4	748
camphene	79-92-5	720
propanoic acid, 2-methyl-, 2-methylpropyl ester	97-85-8	585
methacrolein	78-85-3	542
2-butoxy-ethanol	111-76-2	447
2-butenoic acid, 3-methyl-, pentyl ester	56922-72-6	375
2(10)-pinen-3-one	30460-92-5	318
trans-ocimene	3779-61-1	199
carene isomer	e.g. 13466-78-9	183
butane	106-97-8	156
cis-ocimene	3338-55-4	139
propene, 2-methyl-	115-11-7	128
	Total Conc. (µg/m³)	58,409

26. Laundry product (FF, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	591,918
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	3,284
1,4-dioxane	123-91-1	1,914
ethyl ether	60-29-7	654
acetaldehyde	75-07-0	609
cumene	98-82-8	295
methanol	67-56-1	209
dodecane	112-40-3	182
undecane	1120-21-4	179
1,3-dioxan-5-ol	4740-78-7	153
	Total Conc. (µg/m³)	599397

27. Laundry product (FF, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	604,280
methoxy ethane	540-67-0	42,534
2-methoxy propane	598-53-8	12,299
ethyl formate	109-94-4	3,399
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	3,251
chloromethane	74-87-3	1,304
acetaldehyde	75-07-0	1,114
diethoxy methane	462-95-3	168
chloroethane	75-00-3	142
	Total Conc. (µg/m³)	668,491

28. Laundry product (FF, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	9,421
methanol	67-56-1	1,460
acetaldehyde	75-07-0	267
carbon disulfide	75-15-0	111
	Total Conc. (µg/m³)	11,259

29. Laundry product (FF, R)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	4,964
2-butanone (methyl ethyl ketone)	78-93-3	1,527
undecane	1120-21-4	199
acetaldehyde	75-07-0	194
	Total Conc. (µg/m³)	6,884

30. Laundry product (FF, G)

Compound	CAS #	Conc. (µg/m³)
methanol	67-56-1	51,767
dimethyl ether	115-10-6	26,599
ethanol	64-17-5	2,056
methyl butanoate	623-42-7	717
methyl propionate	554-12-1	681
methyl pentanoate	624-24-8	574
pentane	109-66-0	358
methyl hexanoate	106-70-7	353
acetone	67-64-1	239
1-propanol	71-23-8	167
methyl acetate	79-20-9	154
undecane	1120-21-4	107
2,2,3-trimethylpentane	560-21-4	101
	Total Conc. (µg/m³)	83,872

31. Laundry product (FF, G)

Compound	CAS #	Conc. (µg/m³)
ethanol	64-17-5	297,359
acetone	67-64-1	21,835
methanol	67-56-1	14,465
isopropyl alcohol	67-63-0	13,142
1,4-dioxane	123-91-1	290
2-methoxy propane	598-53-8	196
butane	106-97-8	164
carbonyl sulfide	463-58-1	129
	Total Conc. (µg/m³)	347,580

32. Cleaner (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	64,572
isopropyl alcohol	67-63-0	34,404
ɣ-terpinene	99-85-4	13,388
β-pinene	127-91-3	7,992
α-terpinolene	586-62-9	6,588
α-terpinene	99-86-5	5,588
Isocineole	470-67-7	3,982
α-pinene	80-56-8	3,877
methanol	67-56-1	3,508
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	3,047
camphene	79-92-5	1,546
2-ethenyltetrahydro-2,6,6-trimethyl-2H-pyran	7392-19-0	783
α-phellandrene	99-83-2	728
trans-ocimene	3779-61-1	716
cis-ocimene	3338-55-4	691
α-fenchene	471-84-1	554
acetone	67-64-1	444
1-methyl-1,4-cyclohexadiene	4313-57-9	367
dodecane	112-40-3	250
menthone	89-80-5	223
butane	106-97-8	172
α-thujene	2867-05-2	172
β-phellandrene	555-10-2	154
undecane	1120-21-4	122
	Total Conc. (µg/m³)	153,868

33. Personal care product (F, G)

Compound	CAS #	Conc. (µg/m³)
isopropyl alcohol	67-63-0	3,481
d-limonene	138-86-3	2,836
ethanol	64-17-5	556
methanol	67-56-1	424
acetone	67-64-1	268
β-pinene	127-91-3	190
butane	106-97-8	187
acetaldehyde	75-07-0	174
carbonyl sulfide	463-58-1	127
pentane	109-66-0	110
	Total Conc. (µg/m³)	8,353

34. Cleaner (F, G)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	122,889
β-pinene	127-91-3	4,513
isopropyl alcohol	67-63-0	3,660
α-pinene	80-56-8	1,632
6-methyl-5-hepten-2-one	110-93-0	1,466
acetaldehyde	75-07-0	564
β-phellandrene	555-10-2	417
methanol	67-56-1	323
ɣ-terpinene	99-85-4	266
ethanol	64-17-5	233
3,4-dimethyl-3-cyclohexene-1-carboxaldehyde (triplal isomer)		217
butane	106-97-8	196
α-terpinene	99-86-5	173
α-terpinolene	586-62-9	148
carene isomer	e.g. 13466-78-9	147
carbonyl sulfide	463-58-1	137
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	129
α-phellandrene	99-83-2	122
acetone	67-64-1	118
	Total Conc. (µg/m³)	137,350

35. Cleaner (F, G)

Compound	CAS #	Conc. (µg/m³)
isopropyl alcohol	67-63-0	144,426
acetone	67-64-1	3,117
ethanol	64-17-5	803
butane	106-97-8	171
2,7-dimethyl-2,7-octanediol	19781-07-8	121
carbonyl sulfide	463-58-1	117
	Total Conc. (µg/m³)	148,755

36. Laundry product (F, R)

Compound	CAS #	Conc. (µg/m³)
d-limonene	138-86-3	4,310
methanol	67-56-1	456
2,7-dimethyl-2,7-octanediol	19781-07-8	346
butane	106-97-8	179
(z)-2-(3,3-dimethylcyclohexylidene)ethanol	26532-23-0	159
acetone	67-64-1	154
acetaldehyde	75-07-0	152
β-pinene	127-91-3	133
carbonyl sulfide	463-58-1	125
isopropyl alcohol	67-63-0	112
ethanol	64-17-5	103
	Total Conc. (µg/m³)	6,229

37. Air freshener (F, R)

Compound	CAS #	Conc. (µg/m³)
acetone	67-64-1	2,660,992
propane	74-98-6	396,699
d-limonene	138-86-3	120,853
isobutane	75-28-5	60,723
β-pinene	127-91-3	50,027
α-pinene	80-56-8	25,819
ɣ-terpinene	99-85-4	9,236
2,2-diethoxypropane	126-84-1	7,338
β-phellandrene	555-10-2	7,162
butane	106-97-8	7,053
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	4,773
1-propen-2-ol, formate	32978-00-0	2,811
α-terpinene	99-86-5	2,384
α-phellandrene	99-83-2	1,991
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	1,755
camphene	79-92-5	1,578
2,4-dimethylpentane	108-08-7	389
α-terpinolene	586-62-9	329
2,3-dimethylpentane	565-59-3	236
e-2-butene	624-64-6	224
cis-ocimene	3338-55-4	184
	Total Conc. (µg/m³)	3,362,556

Supplementary Table 2
Fragranced Products (n=31): Compounds regulated as toxic or hazardous

Compound	CAS #	Prevalence (# of products)	CAA-TFS	CAA-HAP	CERCLA	CWA	EPCRA	FIFRA	OSH ACT	RCRA
d-limonene	138-86-3	28						√		
ethanol	64-17-5	23						√	√	
α-pinene	80-56-8	23						√		
acetone	67-64-1	18			√			√	√	√
acetaldehyde *	75-07-0	11	√	√	√	√	√		√	√
butane	106-97-8	8	√							
camphor	76-22-2	8						√	√	
isopropyl alcohol	67-63-0	8					√	√	√	
methanol	67-56-1	8		√	√		√	√	√	√
linalool	78-70-6	7						√		
1-butanol, 3-methyl-, acetate	123-92-2	6			√	√			√	
ethyl acetate	141-78-6	5			√			√	√	√
2-methyl-2-propanol	75-65-0	4					√	√	√	
2-butanone	78-93-3	4		√	√		√		√	√
carbonyl sulfide	463-58-1	4	√	√	√		√			
1,4-dioxane*	123-91-1	3		√	√		√		√	√
cyclohexane	110-82-7	3			√	√	√	√	√	
n,n-dimethyl acetamide	127-19-5	3							√	
pentane	109-66-0	2	√					√	√	
2-butoxy-ethanol	111-76-2	2						√	√	
5-methyl-3-heptanone	541-85-5	2							√	
formaldehyde*	50-00-0	2	√	√	√	√	√	√	√	√
propene, 2-methyl-	115-11-7	2	√							
acetic acid, butyl ester	123-86-4	1			√	√			√	
benzaldehyde	100-52-7	1						√		
butanal	123-72-8	1					√			
chloromethane	74-87-3	1	√	√	√	√	√		√	√
cumene	98-82-8	1		√	√		√		√	√
e-2-butene	624-64-6	1	√							
heptane	142-82-5	1							√	
hexane	110-54-3	1		√	√		√		√	
isobutane	75-28-5	1	√							
octane	111-65-9	1							√	
propane	74-98-6	1	√						√	
methylene chloride*	75-09-2	1		√	√	√	√	√	√	√

*Classified as probable carcinogen by EPA (2007)

Supplementary Table 3
Fragrance-Free Products (n=6): Compounds regulated as toxic or hazardous

Compound	CAS #	Prevalence (# of products)	CAA-TFS	CAA-HAP	CERCLA	CWA	EPCRA	FIFRA	OSH ACT	RCRA
ethanol	64-17-5	6						√	√	
acetaldehyde*	75-07-0	4	√	√	√	√	√		√	√
methanol	67-56-1	4		√	√		√	√	√	√
1,4-dioxane*	123-91-1	2		√	√		√		√	√
2-methyl-2-propanol	75-65-0	2					√	√	√	
acetone	67-64-1	2			√			√	√	√
1-propanol	71-23-8	1						√	√	
2-butanone	78-93-3	1		√	√		√		√	√
butane	106-97-8	1	√							
carbon disulfide	75-15-0	1	√	√	√	√	√	√	√	√
carbonyl sulfide	463-58-1	1	√	√	√		√			
chloroethane	75-00-3	1	√	√	√	√	√		√	
chloromethane	74-87-3	1	√	√	√	√	√		√	√
cumene	98-82-8	1		√	√		√		√	√
dimethyl ether	115-10-6	1	√							
ethyl ether	60-29-7	1	√		√				√	√
ethyl formate	109-94-4	1						√	√	
isopropyl alcohol	67-63-0	1					√	√	√	
methyl acetate	79-20-9	1							√	
pentane	109-66-0	1	√					√	√	

*Classified as probable carcinogen by EPA (2007)

Supplementary Table 4
Green Products (n=17): Compounds regulated as toxic or hazardous

Compound	CAS #	Prevalence (# of products)	CAA-TFS	CAA-HAP	CERCLA	CWA	EPCRA	FIFRA	OSH ACT	RCRA
d-limonene	138-86-3	14						√		
acetone	67-64-1	13			√			√	√	√
α-pinene	80-56-8	11						√		
ethanol	64-17-5	11						√	√	
butane	106-97-8	7	√							
camphor	76-22-2	7						√	√	
methanol	67-56-1	7		√	√		√	√	√	√
isopropyl alcohol	67-63-0	6					√	√	√	
1-butanol, 3-methyl-, acetate	123-92-2	4			√	√			√	
acetaldehyde*	75-07-0	4	√	√	√	√	√		√	√
carbonyl sulfide	463-58-1	4	√	√	√		√			
1,4-dioxane*	123-91-1	3		√	√		√		√	√
linalool	78-70-6	3						√		
pentane	109-66-0	3	√					√	√	
2-butoxy-ethanol	111-76-2	2						√	√	
1-propanol	71-23-8	1						√	√	
2-butanone	78-93-3	1		√	√		√		√	√
5-methyl-3-heptanone	541-85-5	1							√	
butanal	123-72-8	1					√			
cyclohexane	110-82-7	1			√	√	√	√	√	
dimethyl ether	115-10-6	1	√							
heptane	142-82-5	1							√	
hexane	110-54-3	1		√	√		√		√	
methyl acetate	79-20-9	1							√	
methylene chloride*	75-09-2	1		√	√	√	√	√	√	√
octane	111-65-9	1							√	
propene, 2-methyl-	115-11-7	1	√							

*Classified as probable carcinogen by EPA (2007)

Supplementary Table 5
Regular Products (n=20): Compounds regulated as toxic or hazardous

Compound	CAS #	Prevalence (# of products)	CAA-TFS	CAA-HAP	CERCLA	CWA	EPCRA	FIFRA	OSH ACT	RCRA
d-limonene	138-86-3	14						√		
ethanol	64-17-5	18						√	√	
α-pinene	80-56-8	12						√		
acetaldehyde*	75-07-0	11	√	√	√	√	√		√	√
acetone	67-64-1	7			√			√	√	√
2-methyl-2-propanol	75-65-0	6					√	√	√	
ethyl acetate	141-78-6	5			√			√	√	√
methanol	67-56-1	5		√	√		√	√	√	√
2-butanone	78-93-3	4		√	√		√		√	√
linalool	78-70-6	4						√		
isopropyl alcohol	67-63-0	3					√	√	√	
n,n-dimethyl acetamide	127-19-5	3							√	
1,4-dioxane*	123-91-1	2		√	√		√		√	√
1-butanol, 3-methyl-, acetate	123-92-2	2			√	√			√	
butane	106-97-8	2	√							
chloromethane	74-87-3	2	√	√	√	√	√		√	√
cumene	98-82-8	2		√	√		√		√	√
cyclohexane	110-82-7	2			√	√	√	√	√	
formaldehyde*	50-00-0	2	√	√	√	√	√	√	√	√
5-methyl-3-heptanone	541-85-5	1							√	
acetic acid, butyl ester	123-86-4	1			√	√			√	
benzaldehyde	100-52-7	1						√		
camphor	76-22-2	1						√	√	
carbon disulfide	75-15-0	1	√	√	√	√	√	√	√	√
carbonyl sulfide	463-58-1	1	√	√	√		√			
chloroethane	75-00-3	1	√	√	√	√	√		√	
e-2-butene	624-64-6	1	√							
ethyl ether	60-29-7	1	√		√				√	√
ethyl formate	109-94-4	1						√	√	
isobutane	75-28-5	1	√							
propane	74-98-6	1	√						√	
propene, 2-methyl-	115-11-7	1	√							

*Classified as probable carcinogen by EPA (2007)