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Fragranced consumer products: Chemicals emitted, ingredients unlisted

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ABSTRACT

Fragranced consumer products are pervasive in society. Relatively little is known about the composition of these products, due to lack of prior study, complexity of formulations, and limitations and protections on ingredient disclosure in the U.S. We investigated volatile organic compounds (VOCs) emitted from 25 common fragranced consumer products—laundry products, personal care products, cleaning supplies, and air fresheners—using headspace analysis with gas chromatography/mass spectrometry (GC/MS). Our analysis found 133 different VOCs emitted from the 25 products, with an average of 17 VOCs per product. Of these 133 VOCs, 24 are classified as toxic or hazardous under U.S. federal laws, and each product emitted at least one of these compounds. For "green" products, emissions of these compounds were not significantly different from the other products. Of all VOCs identified across the products, only 1 was listed on any product label, and only 2 were listed on any material safety data sheet (MSDS). While virtually none of the chemicals identified were listed, this nonetheless accords with U.S. regulations, which do not require disclosure of all ingredients in a consumer product, or of any ingredients in a mixture called "fragrance." Because the analysis focused on compounds emitted and listed, rather than exposures and effects, it makes no claims regarding possible risks from product use. Results of this study contribute to understanding emissions from common products, and their links with labeling and legislation.

1. Introduction

In the U.S. and other countries, exposure to volatile organic compounds (VOCs) occurs mainly indoors from the use of common products (Wallace, 2001; Edwards et al., 2006). Fragranced products can emit a variety of VOCs (e.g., Wallace et al., 1991; Cooper et al., 1992, 1995; Nazaroff and Weschler, 2004), and some of them, such as limonene, can dominate VOCs found in homes (Wallace, 1987; Edwards et al., 2001a,b; Gokhale et al., 2008). Exposure to fragranced products has been associated with health effects such as asthmatic exacerbations, headaches, mucosal symptoms, and contact allergy (e.g., Millqvist and Löwhagen, 1996; Kumar et al., 1995; Kelman, 2004; Elberling et al., 2005; Caress and Steinemann, 2004, 2005; Johansen, 2003; Rastogi et al., 2007). On the other hand, many studies have evaluated the safety of fragrance ingredients (e.g., Bickers et al., 2003; Ford et al., 2000; Cadby et al., 2002; Smith, 2003, 2004; Smith et al., 2004), and additional studies have found no evidence that fragranced product exposure is associated with indoor air health risks or asthma (IEH, 1996; Opiekun et al., 2003; IOM, 2000). Yet fragrance-free policies have been implemented that restrict the use of scented products in workplaces and other environments (e.g., CDCP, 2009; USAB, 2000; CCOHS, 2010). Given these phenomena, the question emerges: What is emitted from these products? A challenge in answering this question is that emissions from widely used products have not been well characterized and reported. Another challenge is that ingredient disclosure requirements and practices vary, and products may list numerous ingredients, some ingredients, only general terms, or no ingredients. Consequently, information on product labels and material safety data sheets (MSDSs) is generally insufficient to understand product constituents, and their potential relationships with exposures, effects, and policies. This article investigates and provides results on fragranced consumer product emissions, and compares these findings to ingredients listed and legislation, which can contribute to our understanding and consideration of these issues.

"Fragranced consumer products," as termed in this article, refers to products with a fragrance or scent, such as air fresheners, deodorizers, laundry detergents, fabric softeners, dishwashing detergents, hand sanitizers, personal care products, baby shampoo, and cleaning supplies. These products are widely used by individuals, industries, and institutions. For instance, an estimated 37% of the households in America use a best-selling laundry detergent (MarketResearch, 2007); one analyzed in our study. Product formulations are typically complex. In addition to the

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"product base" mixture, a single "fragrance" in a product may contain up to several hundred substances (Bickers et al., 2003) among more than 2600 substances, both natural and synthetic, documented as fragrance ingredients (Ford et al., 2000; Bickers et al., 2003). Formulations are also confidential, and no U.S. regulation requires the disclosure of any ingredient in a fragrance mixture, or of all ingredients in consumer products (Steinemann, 2009).

Despite the ubiquity of fragranced consumer products, relatively few prior studies have investigated the array of VOCs they emit. Wallace et al. (1991) and Cooper et al. (1992) analyzed 31 fragranced consumer products, such as perfumes, fabric softeners, and air fresheners. Rastogi et al. (2001) tested 59 domestic and occupational products, such as soaps, cleaning supplies, and laundry products, for 19 target fragrance compounds associated with hand eczema. Jo et al. (2008) investigated VOC emissions of 26 gel-type air fresheners from the Korean market. Some studies (e.g., Destaillats et al., 2006; Sarwar et al., 2004; Singer et al., 2006), which analyzed secondary emissions,[2] also examined specific VOCs (such as terpenes) emitted from a select set of fragranced products (such as air fresheners).

The research reported in this article is, to the best of our knowledge, the first study since the early 1990s to elucidate the range of VOCs emitted from a variety of widely used fragranced consumer products in the U.S. It builds upon and extends the recent work of Steinemann (2009), and previously noted studies, by testing a larger assortment and number of fragranced consumer products, calculating headspace concentrations, and comparing more extensively the identified VOCs with product labels, MSDSs, and regulations. While studies over the past decades have investigated VOCs emitted from consumer products in general (e.g., Knöppel and Schauenburg, 1989; Kwon et al., 2008; Sack et al., 1992), this work is one of the few to investigate fragranced consumer products in particular.

In this study, we (1) identify the range of VOCs emitted from 25 fragranced consumer products, (2) estimate their headspace concentrations, and (3) determine whether and how identified VOCs are listed on product labels and MSDSs. An overall goal of the study is to provide recent data on chemicals emitted by common consumer products, and to compare these emissions with ingredients listed, which can contribute to broader discussion.

2. Methods

Our study used gas chromatography/mass spectrometry (GC/MS) headspace analysis to identify VOCs emitted from 25 fragranced consumer products, which we categorize as follows: 4 "laundry products" (detergents, dryer sheets, and fabric softener), 9 "personal care products" (soaps, hand sanitizer, lotions, deodorant, shampoo, and baby shampoo), 4 "cleaning supplies" (household and industrial cleaning supplies, disinfectants, and dish detergent), and 8 "air fresheners" (sprays, gels, solids, and deodorant disks). Specific products were selected that are widely used in residential, occupational, or institutional environments in the U.S. (or a combination of them). Each of these 25 products is ranked in the top 5 in annual U.S. sales in their market categories (given available market data),[3] and more than half are the top-selling brand.[4]

Sample preparation, GC/MS analysis, and data reduction proceeded as follows.[5] Headspace samples were prepared by placing approximately 2 g of each consumer product in individual, clean 0.5 liter glass flasks that initially contained only ambient laboratory air, followed by equilibration for at least 24 h at room temperature. Samples were then analyzed for VOCs, once for each sample, using an Agilent 6890/5973 GC/MS system interfaced to an Entech 7100A cryogenic preconcentrator. The preconcentration system was operated in the microscale purge-and-trap (MPT) mode. Analysis generally followed the guidelines found in U.S. EPA Compendium Method TO-15 (EPA, 1999).

On each day that analyses were performed, a nominally hydrocarbon-free (typically, all VOCs have concentrations less than 0.2 ppb) air blank was analyzed to ensure that the GC/MS was free of contamination, and a calibration mixture containing 62 VOCs at 2 to 10 ppb in air was analyzed to check instrument calibration and performance. Three internal standard compounds, benzene-d_6, toluene-d_8, and chlorobenzene-d_5, were analyzed along with each blank, standard, and headspace sample.

Headspace VOC concentrations were calculated by using relative response factors of surrogate compounds. The top 20 peaks by total ion current area were selected from each sample chromatogram and identified by mass spectral library matches, using the 2002 library from the National Institute of Standards and Technology, and considering the consistency of the match's structure and molecular weight with its observed retention time. In some cases, fewer than 20 peaks were identified because peak areas fell either at or below a signal-to-noise ratio of approximately 3:1 or the MS library searches were inconclusive. The top 20 peaks captured 95% of the total ion current chromatographic peak area for 19 of the 25 products. For this article, only VOCs with headspace concentrations of greater than 100 $\mu g/m^3$ were reported.[6]

3. Regulatory context

In the U.S., manufacturers of consumer products, and of fragrance formulations, are not required to disclose all ingredients to the public. This section summarizes the U.S. regulations addressing ingredient disclosure in fragranced consumer products.[7] The products analyzed in this study are regulated by either the Consumer Product Safety Commission (CPSC), for laundry products, cleaning supplies, air fresheners, and soap, or the Food and Drug Administration (FDA), for personal care products, excluding soap.[8]

Consumer product ingredients are exempt from disclosure on product labels and MSDSs in several ways. The Consumer Product Safety Act (CPSA),[9] administered by the CPSC, does not require that product labels list any or all ingredients.[10] The Federal Hazardous Substances Act (FHSA),[11] also administered by the CPSC, requires that product labels list any hazardous substance,[12] but does not require that product labels list all ingredients.[13] For fragrance formulations, the general name "fragrance" may be used as the "common or usual name" on the label, rather than the specific chemicals.[14] The Federal Food, Drug,

[2] In addition to primary emissions of VOCs, fragrance VOCs (such as limonene and other terpenes) can react readily with ozone to generate secondary pollutants such as formaldehyde and other aldehydes, the hydroxyl radical, and ultrafine particles (e.g., Fan et al., 2005; Nazaroff and Weschler, 2004; Wainman et al., 2000).

[3] Market data were obtained from MarketResearch (2005, 2007) and from direct communication with company representatives. Product manufacturers are U.S. companies with both domestic and international sales.

[4] We chose not to disclose brand names because it was not central to the objectives of this research, and because it was important to avert any implication that brands other than those tested would contain greater or fewer compounds of possible concern.

[5] Additional details on methods are provided in the Supplemental Document (available online).

[6] This threshold was established to ensure reporting only those compounds emitted from the products.

[7] For additional regulatory details, see Steinemann (2009) and Steinemann and Walsh (2007).

[8] 21 C.F.R. § 701.20.

[9] Pub. L. No. 92-573, 86 Stat. 1207 (1972), codified at 15 U.S.C. §§ 2051–2084 (2002).

[10] 15 U.S.C. § 2063(c).

[11] Federal Hazardous Substances Act, Pub. L. No. 86-613, 74 Stat. 372 (1960), codified as amended at 15 U.S.C. §§ 1261–1273 (2000).

[12] Federal Hazardous Substances Act, Pub. L. No. 86-613, 74 Stat. 372 (1960), codified as amended at 15 U.S.C. §§ 1261–1273 (2000).

[13] 15 U.S.C. § 1261(f).

[14] 15 U.S.C. § 1261(p)(1)(B).

and Cosmetic Act (FFDCA),[15] administered by the FDA, requires that product labels list each ingredient in descending order of predominance,[16] except the designation of "fragrance" may be used instead of listing the ingredients in the fragrance.[17]

Material safety data sheets,[18] required under the Occupational Safety and Health Administration, Hazard Communication Standard,[19] do not need to list all product ingredients, or list fragrance chemicals.[20] Fragrances are also exempt from labeling requirements.[21] A consumer product ingredient does not need to be reported on an MSDS if the manufacturer or importer deems the ingredient to not be hazardous.[22] More generally, the MSDS requirement applies to a consumer product only if its use in the workplace could result in exposures greater than those reasonably experienced by consumers.[23]

Fragrance ingredients are exempt from disclosure in any product. For consumer products regulated by the CPSC, the word "fragrance" does not need to be listed on the label. If the product does list the word "fragrance," the specific ingredients in the fragrance still do not need to be disclosed. For consumer products regulated by the FDA, the label may list the word "fragrance,"[24] or a similar term, such as "perfume," "parfum," "natural fragrance," "pure fragrance," "organic fragrance," etc., even though these terms are not legally defined. Further, an "unscented" or "fragrance-free" product may be a fragranced product, with the addition of a "masking fragrance" to cover the scent.[25] In addition to these general protections, for fragrances and product formulations classified as "trade secrets," ingredients are also exempt from public disclosure requirements.[26]

4. Results and discussion

4.1. VOCs identified

A total of 133 unique VOCs were detected across the 25 fragranced consumer products, giving a total of 421 occurrences of VOCs. Each product emitted between 6 and 20 VOCs.[27] Headspace concentrations ranged from our minimum threshold value of 100 μg/m^3 to a maximum value of over 1,600,000 μg/m^3.[28] The 19 compounds that occurred most frequently (in about 25% of the products) are listed in Table 1. Each of these 19 compounds is documented as a fragrance ingredient (Api et al., 2008; EC, 2010; FMA, 2009; Givaudan, 2009; Sigma-Aldrich, 2009; Takasago, 2009), although certain compounds may also be used in a product base (e.g., ethanol and limonene can be used for cleaning). Complete data on the VOCs identified and estimated headspace concentrations for the 25 products are presented in the Supplemental Table (available online).[29]

Table 1
Most prevalent compounds among 25 products tested.

Compound	CAS #	Prevalence (# of products)
Limonene	138-86-3	23
Alpha-pinene[a]	80-56-8	20
Beta-pinene	127-91-3	20
Ethanol[a]	64-17-5	19
2,4-Dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	14
Benzyl acetate	140-11-4	12
Acetone[a]	67-64-1	12
Delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	12
o-, m-, or p-cymene	527-84-4, 535-77-3, or 99-87-6	10
Camphene	79-92-5	9
Ethyl butanoate	105-54-4	9
Alpha-terpinene	99-86-5	8
Acetaldehyde[a]	75-07-0	8
Camphor[a]	76-22-2	8
3,6-Dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	7
Delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	7
Linalool	78-70-6	7
Beta-phellandrene	555-10-2	6
Gamma-terpinene	99-85-4	6

[a] Classified as toxic or hazardous under federal laws (see Table 2).

4.2. Comparison of results

Wallace et al. (1991), in their analysis of the headspace of 31 fragranced consumer products, identified approximately 150 different VOCs, with 20 found in 8 or more of the products.[30] Cooper et al. (1992, 1995) analyzed 5 of those products, and confirmed 8 VOCs in 3 or more of the products.[31] Rastogi et al. (2001) analyzed methanolic extracts of 59 fragranced domestic and occupational products for 19 target fragrances, and identified 6 target VOCs, other terpenes, and terpineols in 22 or more of the products.[32] Jo et al. (2008) analyzed 26 gel-type air fresheners sold in Korea, and identified more than 84 compounds, with 11 analytes in more than half of the products.[33] Studies of secondary pollutants, generated from fragranced consumer products (such as air fresheners and cleaning supplies), also identified primary emissions of selected VOCs, including limonene and other terpenoids (Sarwar et al., 2004; Destaillats et al., 2006; Singer et al., 2006).

Across these studies, of all the identified VOCs, limonene is the most common. We found this VOC in 92% of the products, Wallace et al. (1991) found it in 74%, Rastogi et al. (2001) in 78%, and Jo et al. (2008) in 58% of the products. Additionally, Sarwar et al. (2004), Destaillats et al. (2006), and Singer et al. (2006) found it in 100% of their products. Other terpenes were also prevalent. We found alpha-pinene in 84% and beta-pinene in 80% of the products, Wallace et al. (1991) and Rastogi et al. (2001) both found alpha-pinene in 39%, and Jo et al. (2008) found alpha-pinene in 31%. Other prevalent compounds were ethanol (76% of our products; 74% of Wallace et al., 1991; and 65% of Jo et al., 2008), benzyl acetate (52% of our products; and 48% of Wallace et al., 1991), and acetone (48% of our

[15] Pub. L. No. 75-717, 52 Stat. 1040, codified at 21 U.S.C. §§ 321–397 (2000).
[16] 21 C.F.R. § 701.3(a).
[17] 21 C.F.R. § 701.3(a).
[18] Chemical manufacturers and importers are required to obtain or develop an MSDS for each hazardous chemical they produce or import, and employers are required to have an MSDS in the workplace for each hazardous chemical they use. 5 C.F.R. § 1910.1200(g)(1).
[19] 5 C.F.R § 1910.1200.
[20] 5 C.F.R § 1910.1200(g)(2).
[21] 5 C.F.R § 1910.1200(b)(5)(iii).
[22] 5 C.F.R § 1910.1200(g)(2).
[23] 5 C.F.R § 1910.1200(b)(6)(ix).
[24] 21 C.F.R. § 701.3.
[25] 21 C.F.R. § 701.3(a).
[26] 5 U.S.C. § 552(b)(4); 21 C.F.R. § 701.3(a); 15 U.S.C. § 2055(a)(1); 5 U.S.C. § 552(b)(4).
[27] Some products emitted more than 20 VOCs above our threshold of 100 mg/m^3, but we limited reporting to the top 20.
[28] The minimum reported concentration was associated with several compounds near the threshold; the maximum concentration was associated with ethanol.
[29] We note that headspace concentrations are not the same as ambient concentrations, and are typically higher.

[30] Ethanol, limonene, linalool, beta-phenethyl alcohol, beta-myrcene, benzyl acetate, benzyl alcohol, benzaldehyde, alpha-terpineol, ocimene, beta-citronellol, alpha-pinene, acetone, ethyl acetate, gamma-terpinene, 1,8-cineole, alpha-terpinolene, nerol, camphor, and methylene chloride.
[31] Limonene, linalool, benzyl acetate, alpha-pinene, camphene, myrcene, benzaldehyde, and beta-phenethyl alcohol.
[32] Limonene, linalool, citronellol, eucalyptol, geraniol, alpha-pinene.
[33] Toluene, bis(trimethylsilyl)acetylene, benzene, hexamethylcyclotrisiloxane, pentadecane, ethanol, ethyl benzene, limonene, m,p-xylene, and tetramethylsilane.

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Table 2
VOCs identified that are classified as toxic or hazardous under federal laws.

Compound	CAS #	Prevalence (# of products)	CAA-HAP	CAA-RTFS	CERCLA	CWA	EPCRA	FIFRA	OSH Act	RCRA
Alpha-pinene	80-56-8	20						√		
Ethanol	64-17-5	19						√	√	
Acetone	67-64-1	12			√			√	√	
Acetaldehyde[a]	75-07-0	8	√	√	√		√		√	
Camphor	76-22-2	8						√	√	
Ethyl acetate	141-78-6	5			√			√	√	
Isoamyl acetate	123-92-2	6			√				√	
2-Butanone	78-93-3	4			√		√		√	√
Methanol	67-56-1	4	√		√		√	√	√	
Tert-butyl alcohol	75-65-0	3					√	√	√	
Cyclohexane	110-82-7	3			√		√	√	√	
n,n-Dimethyl acetamide	127-19-5	3							√	
1,4-Dioxane[a]	123-91-1	3	√		√		√		√	√
Isopropyl alcohol	67-63-0	3					√	√	√	
2-Butoxy ethanol	111-76-2	2						√	√	
Formaldehyde[a]	50-00-0	2	√	√	√		√	√	√	√
n-Hexane	110-54-3	1	√		√		√		√	
5-Methyl-3-heptanone	541-85-5	2							√	
2-Methyl-propene	115-11-7	2		√						
Benzaldehyde	100-52-7	1						√		
Butanal	123-72-8	1					√			
Chloromethane	74-87-3	1	√	√	√	√	√		√	√
Cumene	98-82-8	1	√		√		√		√	
Methylene chloride[a]	75-09-2	1	√	√	√	√	√	√	√	√

CAA-HAP: Clean Air Act—Hazardous Air Pollutant.
CAA-RTFS: Clean Air Act—Regulated Toxic or Flammable Substances.
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act—Hazardous Substance.
CWA: Clean Water Act—Priority Pollutant.
EPCRA: Emergency Planning and 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.
[a] Classified as probable carcinogen by EPA (2007).

products; and 35% of Wallace et al., 1991). Thus, these results indicate that the terpenes limonene, alpha-pinene, and beta-pinene, as well as ethanol, benzyl acetate, and acetone, are among the most common volatile chemicals—among thousands of possibilities—in fragranced consumer products.

4.3. Regulatory aspects

Of the 133 unique VOCs identified in this study, 24 are classified as toxic or hazardous under at least one federal law (Table 2). Each product emitted between 1 and 8 of these chemicals. Referring back to Table 1, of the 19 most frequently occurring chemicals in the products, 5 are classified as toxic or hazardous. Also, 11 (44%) of the products emitted 1 or more carcinogenic "Hazardous Air Pollutants" (HAPs), which have no safe threshold of exposure, according to the U.S. Environmental Protection Agency (EPA, 1994, 2005, 2007). While the carcinogenic HAPs have no safe exposure level (under the Clean Air Act), some of these compounds do have exposure levels set under other federal laws (e.g., Permissible Exposure Limits under the Occupational Safety and Health Act), and under state laws (e.g., Safe Harbor Levels under Proposition 65 in California). However, like the Clean Air Act, the federal laws would not necessarily address these products, or their use in residences and other indoor environments (Steinemann and Walsh, 2007), where primary exposure to many HAPs and other VOCs occurs (Sack et al., 1992).

This assessment of product VOCs classified as toxic or hazardous cannot determine whether product usage would pose risks. Thus, the focus of this paper is on chemical identities, noting which are currently classified as toxic or hazardous under one or more federal laws, and thus might merit consideration for further study. Other chemicals identified may also be of interest for further study because of their potential to generate secondary pollutants (e.g., terpenes that react with ozone to generate aldehydes and ultrafine particles), interactions with other chemicals, individual susceptibilities, or other reasons.

4.4. Chemical disclosure on labels and MSDSs

Among the 133 unique VOCs identified across the products, only 1 VOC (ethanol in 2 products) was listed on any of the product labels, and only 2 VOCs (ethanol in 5 products, and 2-butoxyethanol in 1 product) were listed on any of the MSDSs.[34]

The listing of ingredients varied among products and by the regulation governing the products (Table 3). Of the 25 products, 17 are regulated by the CPSC, and 8 by the FDA. For the 17 products regulated by the CPSC: On the labels, 9 listed no ingredients, 6 listed only general terms (such as "cleaning agents," "quality control ingredients," "softeners," or "biodegradable surfactants"), and 3 of the products listed the word "fragrance," "perfume," or "essential oils." On the MSDSs, 9 listed the term "fragrance," "perfume," or "essential oils," and 1 of these products also listed the term on the label. For the 8 products regulated by the FDA: On the labels, each one listed specific ingredients, plus the general word "fragrance" (7 products) or "essential oil" (1 product). On the MSDSs, 2 products listed no ingredients, 1 product listed the word "fragrance," but 7 did not list "fragrance."

In summary, 9 products listed no ingredients on the product label, 6 listed only general terms (such as "cleaning agents") on the label, and 3 products listed no ingredients on the MSDS. Additionally, 14 products did not list "fragrance" (or a similar term) on the product label, 15 products did not provide it on the MSDS, and 6 products did not provide it on either the label or the MSDS. Yet each of the 25

[34] We did not provide specific wording from product labels and MSDSs because it could lead to the identification of product brands.

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Table 3
Types of ingredients listed on product labels and MSDSs.[a]

Ingredients listed	Product labels		Product MSDSs	
	CPSA	FFDCA	CPSA	FFDCA
None	9	0	1	2
Only general terms	6	0	9	0
Chemical name and general terms	2	8	7	6
Fragrance term[b] listed	3	8	9	1
Fragrance term not listed	14	0	8	7

[a] Numbers of fragranced consumer products out of 17 and 8 total products regulated under the CPSA and FFDCA, respectively.
[b] "Fragrance term" includes "fragrance," "perfume," or "essential oils."

products is fragranced, as determined by product advertising (e.g., "original scent"), labeling, or functionality (a scented air freshener), and each appears to be in compliance with their respective laws for providing (or not providing) the word "fragrance" in the list of ingredients on the product label. It was not possible to determine, given available product data, whether they were in compliance with MSDS regulations.

4.5. "Green" products

Of the 25 products, 11 made some claim of "green" or a related word, such as "organic," "non-toxic," or "natural," on their labeling or MSDS. Each of these 11 "green" products emitted at least 2 VOCs classified as toxic or hazardous, and 4 emitted at least 1 carcinogen (1,4-dioxane, methylene chloride, or acetaldehyde). Comparing the 11 "green" and 14 other products, no statistically significant difference ($p<0.05$) was found between the number of chemicals classified as toxic or hazardous, or the number of carcinogens.[35] Moreover, taking into account product advertising (e.g., product websites), in addition to product labeling and MSDSs, 19 of the products made some claim of "green" or a related word. Again, no statistically significant difference was found between the number of chemicals classified as toxic or hazardous, or the number of carcinogens, emitted from the 19 "green" products and the 6 other products.[36]

4.6. Limitations

This study focused on VOCs, and other product ingredients and emissions, such as semivolatile organic compounds, could be investigated. The GC/MS headspace analysis measured primary VOC emissions, directly from each product, while the possible generation of secondary pollutants, or interactions with other chemicals, could also be investigated. Because complete product and fragrance formulations were not available from manufacturers, it was not possible to determine whether an identified VOC was contained in the fragrance mix, in the product base, or both. Finally, this study did not seek to assess, and makes no claims regarding, whether product usage would be associated with any risks.

5. Conclusions

Our study provides recent and relevant results on the range of VOCs emitted by common fragranced consumer products. Virtually none of these VOCs were listed on any product label or MSDS. Overall, "green" product emissions of VOCs classified as toxic or hazardous, or as carcinogens, were not significantly different from the other products. Because our study did not analyze exposures or effects, it can draw no conclusion regarding possible risks from product usage.

Collectively, these 25 fragranced products emitted 133 different VOCs, and 24 of these VOCs are classified as toxic or hazardous under federal laws. Of the 133 unique VOCs identified across the products, only 1 was listed on any product label, and only 2 were listed on any MSDS. None of the products listed all chemicals emitted, and 14 of the product labels did not list "fragrance" (or a similar word), yet this appears to comply with U.S. laws.

Results of this study contribute to understanding consumer product emissions, and to broader considerations, such as the following: Should ingredients be disclosed and, if so, using what criteria? How can company formulations be protected? Should specific chemicals be listed, or general terms (such as "cleaning agent" or "fragrance")? Would listing all product chemicals, potentially hundreds, create false alarm? Or would listing some (but not all) ingredients create false assurance? Do the emissions from these products pose a risk, and are there levels at which the risk is de minimis? Should risk or exposure be a criterion for disclosure? Should claims of "green" or "organic" on consumer products have regulatory definitions, and would listing ingredients help to substantiate the claims? If a specific chemical is found in a "fragrance mixture" or a "product base," should it matter for disclosure requirements? With widespread attention to consumer products, these findings can contribute to further study and collaboration among scientists, policy makers, producers, and the public.

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[35] We chose this straightforward metric, recognizing that comparisons among products and chemicals are complex and can be performed in different ways. Two-sample t-tests and Chi-Squared tests all yielded p-values greater than 0.30.
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Supplemental Document

Gas Chromatography/Mass Spectrometry (GC/MS) Analysis.

Approximately 2 grams of each consumer product was added to individual, clean 0.5 liter custom-modified glass sidearm bottles that initially contained only ambient laboratory air. The bottles were sealed with Teflon-lined screw caps, and volatile constituents in the products were allowed to equilibrate into the headspace of the flask for at least 24 hours at room temperature. Each bottle's sidearm was fitted with a septum that allowed for the withdrawal of headspace vapors using a gas-tight syringe. Consumer product samples were sealed inside the bottles and stored at room temperature for no more than 21 days before analysis.

Samples (1 – 10 mL aliquots at approximately T = 22°C and P = 750 mm Hg) were analyzed for VOCs using an automated Agilent 6890/5973 GC/MS system interfaced to an Entech 7100A cryogenic preconcentrator operated in the microscale purge-and-trap (MPT) mode. GC/MS analysis of volatile organic species generally followed the guidelines found in U.S. EPA Compendium Method TO-15 (EPA 1999) and more details of similar analyses are presented elsewhere (Cowen et al., 2008; MacGregor et al., 2008). A constant flow of helium was maintained at 1.2 mL/min through an Agilent J&W DB-1 (60 m x 0.32 mm, 1 µm film thickness) column. The oven temperature was programmed by first holding it at 35°C for 5 minutes, then increasing it at 6°C/min to 150°C, followed by an increase of 15°C/min to 220°C, where it remained for 6 minutes (total time 34.8 min). The mass spectrometer was operated in the full scan mode from m/z 25 to 300.

On each day that analyses were performed, a nominally hydrocarbon-free air blank was analyzed to ensure that the GC/MS was free of contamination. Typically, VOCs in the air blank are present at concentrations less than 0.2 parts per billion [ppb] by volume. The blank check was followed by analysis of a TO-15 calibration mixture containing 62 VOCs at either 2 or 10 ppb in air to check instrument calibration, retention times, and overall system performance. Three internal standard compounds (benzene-d_6, toluene-d_8, and chlorobenzene-d_5) were analyzed each at approximately 4.5 ppb along with each blank, standard, and headspace sample. Internal standard responses were used to track and correct for run-to-run variability in the performance of the cryogenic preconcentration system and in mass spectrometer detector response.

Headspace VOC concentrations were calculated by using relative response factors of one of two different surrogate compounds found in the VOC calibration mixture. (Relative response factors were scaled to the total ion current of the toluene-d_8 internal standard response.) Among other factors, the presence of oxygen in a VOC, along with its structure (whether it is aliphatic, aromatic, etc.), and its molecular weight affect the magnitude of its total ion current response in a mass spectrometer. The surrogates selected, 4-ethyl toluene and 2-hexanone, were chosen to represent the approximate mass spectral response of VOCs identified in the headspace samples that do not contain oxygen and those that do, respectively. Ethyl toluene is an aromatic hydrocarbon with a molecular weight and chemical structure similar to that of monoterpenes, whereas 2-hexanone is a carbonyl compound with some aliphatic character and a mid-range VOC molecular weight. In addition, these surrogates were selected because they did not coelute with other compounds in the 62 component calibration mixture, thus allowing for the accurate measurement of their total ion current responses.

Excluding the three internal standards and obvious analytical artifacts (such as polymethylsiloxanes due to column or septum bleed), the top 20 peaks by total ion current area were selected from each sample chromatogram and tentatively identified by mass spectral library matches to compounds in the 2002 library from the National Institute of Standards and Technology. In general, the compound with the highest match probability was selected. Consistency of the proposed match's chemical structure and molecular weight with its observed retention time was also considered. In some cases, these considerations led to selecting a compound with a lower match probability and/or identifying compounds as one of a number of different possible isomers. For some products, fewer than 20 peaks were identified because peak areas fell either at or below a signal-to-noise ratio of approximately 3:1 or the mass spectral library searches were inconclusive. Compounds having estimated concentrations below 100 $\mu g/m^3$ were censored to ensure only a product's primary VOC emissions were reported.

To confirm that identification of the top 20 compounds by peak area produced robust results, alternative reporting thresholds were investigated, such as identifying the compounds comprising up to 99% of the total chromatographic peak area or identifying all compounds except those having areas less than 1% of the total chromatographic peak area. Reporting the top 20 peaks captured 95% of the total ion current chromatographic peak area for 19 of the 25 products. The alternative thresholds produced comparable results.

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25 Products with Headspace Concentrations > 100 µg/m^3

1. Laundry product

Compound	CAS #	µg/m^3
limonene	138-86-3	40800
isocineole	470-67-7	10200
alpha-terpinolene	586-62-9	2450
alpha-terpinene	99-86-5	2060
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	1950
ethanol	64-17-5	1330
gamma-terpinene	99-85-4	1240
beta-pinene	127-91-3	1080
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	920
alpha-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
alpha-phellandrene	99-83-2	584
n,n-dimethyl acetamide	127-19-5	525
6-methyl-5-hepten-2-one	110-93-0	519
beta-phellandrene	555-10-2	221
alpha-fenchene	471-84-1	129
	N	18

2. Laundry product

Compound	CAS #	μg/m^3
ethanol	64-17-5	932000
limonene	138-86-3	33000
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	3990
1,4-dioxane	123-91-1	2230
3,7-dimethyl-1,6-octadiene	10281-56-8	2020
ethyl acetate	141-78-6	1770
alpha-pinene	80-56-8	1620
beta-pinene	127-91-3	1110
2-butanone (methyl ethyl ketone)	78-93-3	1080
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
beta-terpinene	99-84-3	311
benzyl acetate	140-11-4	184
dodecane	112-40-3	182
alpha-terpinene	99-86-5	150
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	108
bornane	464-15-3	100
	N	18

3. Laundry product

Compound	CAS #	µg/m^3
linalool	78-70-6	2720
ethanol	64-17-5	2530
benzyl acetate	140-11-4	1500
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	1430
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	962
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	833
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
alpha-pinene	80-56-8	535
trans-rose oxide	876-18-6	475
eucalyptol (1,8-cineole)	470-82-6	420
benzyl alcohol, alpha-methyl-, acetate (alpha-phenylethyl acetate)	93-92-5	394
beta-pinene	127-91-3	353
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	307
unknown		249
methyl benzoate	93-58-3	208
acetone	67-64-1	148
decanal	112-31-2	124
	N	19

4. Laundry product

Compound	CAS #	µg/m^3
ethanol	64-17-5	810900
limonene	138-86-3	74400
methoxy ethane	540-67-0	7540
alpha-pinene	80-56-8	6920
benzyl acetate	140-11-4	3640
isocineole	470-67-7	3640
beta-pinene	127-91-3	2910
2-methoxy propane	598-53-8	2700
linalool	78-70-6	2630
(z)-3,4-dimethyl-3-hexen-2-one	20685-45-4	2480
chloromethane	74-87-3	2320
gamma-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	1970
acetaldehyde	75-07-0	1810
2,4-dimethyl-1,3-cyclopentanedione	34598-80-6	1490
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	1450
alpha-terpinolene	586-62-9	1130
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
alpha-terpinene	99-86-5	398
	N	20

5. Personal care product

Compound	CAS #	µg/m^3
limonene	138-86-3	36000
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	9460
ethanol	64-17-5	9000
(z)-3,4-dimethyl-3-hexen-2-one	20685-45-4	4220
alpha-pinene	80-56-8	4200
beta-pinene	127-91-3	3320
gamma-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	3240
isocineole	470-67-7	3150
2,4-dimethyl-1,3-cyclopentanedione	34598-80-6	2520
camphor	76-22-2	2460
linalool	78-70-6	2330
benzyl acetate	140-11-4	1930
methanol	67-56-1	1620
camphene	79-92-5	1580
alpha-terpinolene	586-62-9	1010
acetone	67-64-1	1000
beta-terpinene	99-84-3	704
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	556
alpha-terpinene	99-86-5	528
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	456
	N	20

6. Personal care product

Compound	CAS #	μg/m^3
alpha-pinene	80-56-8	10900
ethanol	64-17-5	3120
eucalyptol (1,8-cineole)	470-82-6	2840
limonene	138-86-3	1940
citronella (3,7-dimethyl-6-octenal)	106-23-0	942
camphor	76-22-2	632
gamma-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
beta-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, alpha-methyl-, acetate (alpha-phenylethyl acetate)	93-92-5	255
camphene	79-92-5	238
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	202
alpha-terpinene	99-86-5	149
butane	106-97-8	141
hexane	110-54-3	134

	N	20

7. Personal care product

Compound	CAS #	µg/m^3
ethanol	64-17-5	353700
alpha-pinene	80-56-8	4850
limonene	138-86-3	2340
beta-pinene	127-91-3	2140
ethyl acetate	141-78-6	1800
camphene	79-92-5	1050
1,1-diethoxy-ethane	105-57-7	608
acetaldehyde	75-07-0	500
alpha-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
beta-phellandrene	555-10-2	125
	N	14

8. Cleaner

Compound	CAS #	µg/m^3
ethanol	64-17-5	742800
3-methoxy-3-methylbutanol	56539-66-3	3910
limonene	138-86-3	3110
ethyl acetate	141-78-6	1020
cumene	98-82-8	793
alpha-pinene	80-56-8	306
beta-pinene	127-91-3	193
alpha-terpinene	99-86-5	110
	N	8

9. Personal care product

Compound	CAS #	µg/m^3
ethanol	64-17-5	7720
isopropyl alcohol	67-63-0	2130
3-hexen-1-ol, acetate, (z)-	3681-71-8	1980
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1850
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	1290
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
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	156
hexanoic acid, ethyl ester	123-66-0	150
acetaldehyde	75-07-0	119
acetone	67-64-1	111
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	105
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	104
	N	17

10. Personal care product

Compound	CAS #	µg/m^3
2,2,4,4,6,8,8-heptamethylnonane	4390-43-9	1840
methanol	67-56-1	1100
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
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	unavailable	113
	N	17

11. Personal care product

Compound	CAS #	$\mu g/m^3$
limonene	138-86-3	72900
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	47300
unknown alkane		6140
beta-pinene	127-91-3	5560
ethyl butanoate	105-54-4	3670
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	3650
allyl heptanoate	142-19-8	3120
benzyl acetate	140-11-4	1900
alpha-pinene	80-56-8	1860
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1780
methanol	67-56-1	1280
1-butanol, 3-methyl-, acetate	123-92-2	1220
4-tert-butylcyclohexyl acetate	32210-23-4	1120
2-hexenal	6728-26-3	932
1,4-dioxane	123-91-1	814
gamma-terpinene	99-85-4	636
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	569
unknown alkane		353

	N	18

12. Personal care product

Compound	CAS #	µg/m^3
limonene	138-86-3	48000
ethyl butanoate	105-54-4	4700
benzyl acetate	140-11-4	2810
beta-pinene	127-91-3	1610
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1440
ethanol	64-17-5	1420
allyl heptanoate	142-19-8	978
isopropyl alcohol	67-63-0	952
alpha-pinene	80-56-8	654
methylene chloride	75-09-2	474
gamma-terpinene	99-85-4	380
2,6-dimethyl-2-heptanol	13254-34-7	332
1,4-dioxane	123-91-1	293
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	273
cis-ocimene	3338-55-4	201
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	109
	N	15

13. Cleaner

Compound	CAS #	μg/m^3
ethanol	64-17-5	16500
alpha-pinene	80-56-8	1320
beta-pinene	127-91-3	952
ethyl acetate	141-78-6	492
limonene	138-86-3	343
cyclohexane	110-82-7	109
	N	6

14. Air freshener

Compound	CAS #	µg/m^3
ethanol	64-17-5	1580000
limonene	138-86-3	66900
butanoic acid, 2-methyl-, ethyl ester	7452-79-1	40800
beta-pinene	127-91-3	30400
propanoic acid, 2-methyl-, ethyl ester	97-62-1	17700
3-methyl-2-buten-1-ol acetate (prenyl acetate)	1191-16-8	15700
5-methyl-3-heptanone	541-85-5	12900
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	12400
acetaldehyde	75-07-0	9520
2-methyl-2-propanol (t-butyl alcohol)	75-65-0	7870
gamma-terpinene	99-85-4	7730
1-butanol, 3-methyl-, acetate	123-92-2	6060
alpha-pinene	80-56-8	5600
linalool	78-70-6	5270
6-methyl-5-hepten-2-one	110-93-0	4630
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	4240
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	3490
beta-phellandrene	555-10-2	2040
alpha-thujene	2867-05-2	997
	N	19

15. Cleaner

Compound	CAS #	µg/m^3
1-butoxy-2-propanol	5131-66-8	164000
eucalyptol (1,8-cineole)	470-82-6	3610
n,n-dimethyl acetamide	127-19-5	2780
4-tert-butylcyclohexyl acetate	32210-23-4	1240
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
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	173
2,3-epoxyhexanol	90528-63-5	124
	N	11

16. Cleaner

Compound	CAS #	µg/m^3
eucalyptol (1,8-cineole)	470-82-6	108000
limonene	138-86-3	48000
isocineole	470-67-7	34800
camphor	76-22-2	8280
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	8200
beta-pinene	127-91-3	7400
alpha-pinene	80-56-8	6610
2-butanone (methyl ethyl ketone)	78-93-3	5050
butanal	123-72-8	3900
gamma-terpinene	99-85-4	3790
1-methoxy-4-propylbenzene	104-45-0	2840
alpha-terpinolene	586-62-9	2590
cyclohexane	110-82-7	1790
2-butoxy-ethanol	111-76-2	1430
alpha-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
	N	19

17. Personal care product

Compound	CAS #	μg/m^3
limonene	138-86-3	8960
gamma-terpinene coeluted with 2,7-dimethyl-2,7-octanediol	99-85-4 & 19781-07-8	5140
beta-pinene	127-91-3	2000
alpha-pinene	80-56-8	1000
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
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	279
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	277
alpha-terpinene	99-86-5	216
isocineole	470-67-7	198
propene, 2-methyl-	115-11-7	160
ethylmethyl pentane	609-26-7	112

N 15

18. Air freshener

Compound	CAS #	µg/m^3
limonene	138-86-3	83900
alpha-pinene	80-56-8	43300
beta-pinene	127-91-3	28800
ethanol	64-17-5	20700
ethyl butanoate	105-54-4	15400
ethyl acetate	141-78-6	15100
3-hexen-1-ol (leaf alcohol)	928-96-1	8920
1-butanol, 3-methyl-, acetate	123-92-2	5910
beta-phellandrene	555-10-2	5020
acetaldehyde	75-07-0	3450
benzaldehyde	100-52-7	1940
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	1590
1-methyl-3-(1-methylethyl)-cyclohexene	13828-31-4	1380
isopropyl alcohol	67-63-0	1340
1-butanol, 2-methyl-, acetate	624-41-9	1210
camphene	79-92-5	1180
acetone	67-64-1	1040
methyl butanoate	623-42-7	929
dimethyl ethyl cyclohexene	2228-98-0	446
alpha-thujene	2867-05-2	337
	N	20

19. Air freshener

Compound	CAS #	μg/m^3
limonene	138-86-3	11300
3-methoxy-3-methylbutanol	56539-66-3	4450
linalool	78-70-6	1240
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 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, alpha-methyl-, acetate (alpha-phenylethyl acetate)	93-92-5	463
beta-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
gamma-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
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	103

N 20

20. Air freshener

Compound	CAS #	µg/m^3
linalool	78-70-6	5380
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	4640
3-hexen-1-ol (leaf alcohol)	928-96-1	1130
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	1000
limonene	138-86-3	420
thujone	546-80-5	242
acetone	67-64-1	241
camphor	76-22-2	191
	N	6

21. Air freshener

Compound	CAS #	µg/m^3
limonene	138-86-3	21900
4-tert-butylcyclohexyl acetate	32210-23-4	15200
acetaldehyde	75-07-0	13400
benzyl acetate	140-11-4	13000
2,7-dimethyl-2,7-octanediol	19781-07-8	8250
acetone	67-64-1	8240
ethanol	64-17-5	3430
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	2110
citronellyl acetate	150-84-5	1870
hexanal	66-25-1	1410
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	1240
allyl heptanoate	142-19-8	1190
1-methyl-4-(1-methylethyl)-cyclohexane	6069-98-3	1170
ethyl butanoate	105-54-4	1040
3-hexen-1-ol (leaf alcohol)	928-96-1	1020
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	911
alpha-pinene	80-56-8	451
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	394
	N	18

22. Air freshener

Compound	CAS #	µg/m^3
limonene	138-86-3	135000
1-butanol, 3-methyl-, acetate	123-92-2	24300
hexyl acetate	142-92-7	23000
benzyl acetate	140-11-4	11900
4-(1,1-dimethylethyl)-cyclohexanol	98-52-2	9230
acetone	67-64-1	8320
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	7680
beta-pinene	127-91-3	6360
ethyl butanoate	105-54-4	5910
alpha-pinene	80-56-8	5830
camphor	76-22-2	5690
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	4320
1-methoxy-4-methylbenzene	104-93-8	3880
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	3510
methyl benzoate	93-58-3	2960
trans-rose oxide	876-18-6	2360
2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1)	68039-49-6	2100
beta-phellandrene	555-10-2	1540
camphene	79-92-5	1010
o, m, or p-cymene	527-84-4, 535-77-3, or 99-87-6	842

N 20

23. Air freshener

Compound	CAS #	µg/m^3
benzyl acetate	140-11-4	9520
limonene	138-86-3	3970
acetone	67-64-1	3700
1-butanol, 3-methyl-, acetate	123-92-2	3570
methanol	67-56-1	3380
alpha-pinene	80-56-8	2570
ethanol	64-17-5	1870
acetaldehyde	75-07-0	1730
ethyl butanoate	105-54-4	1330
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 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
beta-pinene	127-91-3	209
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	129
	N	20

24. Air freshener

Compound	CAS #	µg/m^3
limonene	138-86-3	89800
benzyl acetate	140-11-4	18700
1-butanol, 3-methyl-, acetate	123-92-2	17700
hexyl acetate	142-92-7	16000
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	5410
cis-rose oxide (4-methyl-2-(2-methyl-1-propenyl)-tetrahydropyran)	16409-43-1	5100
camphor	76-22-2	4890
beta-pinene	127-91-3	4380
ethyl butanoate	105-54-4	3680
3,6-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra)	67801-65-4	3550
alpha-pinene	80-56-8	3380
methyl benzoate	93-58-3	2400
1-methoxy-4-methylbenzene	104-93-8	2350
acetone	67-64-1	2240
trans-rose oxide	876-18-6	1920
beta-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
alpha-terpinene	99-86-5	352
	N	19

25. Personal care product

Compound	CAS #	µg/m³
limonene	138-86-3	33800
alpha-pinene	80-56-8	5770
linalool	78-70-6	4140
ethanol	64-17-5	3250
camphor	76-22-2	2150
beta-pinene	127-91-3	1660
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	1640
3-methyl-2-butenoic acid, 2-pentyl ester	150462-84-3	1430
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
delta-4-carene, cis-2-carene, trans-2-carene, or delta-3-carene	554-61-0; 5208-49-1; 5208-50-4; 13466-78-9	183
butane	106-97-8	156
cis-ocimene	3338-55-4	139
propene, 2-methyl-	115-11-7	128
	N	20