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Fragranced consumer products: Chemicals emitted, ingredients unlisted

Anne C. Steinemann^{a,*}, Ian C. MacGregor^b, Sydney M. Gordon^b, Lisa G. Gallagher^c, Amy L. Davis^c, Daniel S. Ribeiro^c, Lance A. Wallace^d^a University of Washington, Department of Civil and Environmental Engineering, and Evans School of Public Affairs, Seattle, WA 98195-2700, United States^b Battelle Memorial Institute, United States^c University of Washington, United States^d U.S. Environmental Protection Agency (ret.), United States

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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.

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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

* Corresponding author. Tel.: +1 206 616 2661; fax: +1 206 543 2907.
E-mail address: acstein@u.washington.edu (A.C. Steinemann).

“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., Destailats 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

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.

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 µg/m³ 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,

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/m³ to a maximum value of over 1,600,000 µg/m³.²⁸ 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 terpeneols 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; Destailats 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), Destailats 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/m³, 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.

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.

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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References

- (CCOHS) Canadian Centre for Occupational Health and Safety. Scent-free policy for the workplace; 2010 (http://www.ccohs.ca/oshanswers/hsprograms/scent_free.html (accessed June 3)).
- (CDCP) Centers for Disease Control and Prevention, Department of Health and Human Services. Indoor environmental quality policy CDC-SM-2009-01, section C(1); 2009. (June 22).
- (EC) European Commission. CosIng (cosmetic ingredients & substances); 2010 (<http://ec.europa.eu/consumers/cosmetics/cosing/> (accessed June 8)).
- (EPA) Environmental Protection Agency. Technical background document to support rulemaking pursuant to the Clean Air Act, section 112(g), ranking of pollutants with respect to hazard to human health, EPA-450/3-92-010; 1994. (February).
- (EPA) Environmental Protection Agency. Determination of volatile organic compounds (VOCs) in air collected in specially-prepared canisters and analyzed by gas chromatography/mass spectrometry (GC/MS). Method TO-15. Compendium of methods for the determination of toxic organic compounds in ambient air. EPA/625/R-96/010b. 2nd ed. Cincinnati: US Environmental Protection Agency, Office of Research and Development; 1999. (<http://www.epa.gov/ttnamti1/airtox.html> (accessed February 4, 2010)).
- (EPA) Environmental Protection Agency. Guidelines for carcinogen risk assessment. EPA/630/P-03/001F. Washington, D.C.: Environmental Protection Agency, 2005 March.
- (EPA) Environmental Protection Agency. Prioritized chronic dose-response values for screening risk assessments, Table 1; 2007. (June 12, <http://www.epa.gov/ttn/atw/toxsource/summary.html> (accessed February 4, 2010)).
- (FMA) Fragrance Materials Association. Air freshener fragrance ingredient survey results; 2009. (March 20, <http://www.fmafragrance.org/> (accessed June 9, 2009)).
- (IEH) Institute for Environment and Health. Assessment on indoor air quality in the home: nitrogen dioxide, formaldehyde, volatile organic compounds, house dust mites, fungi and bacteria (assessment A2). Leicester, UK: IEH, University of Leicester; 1996.
- (IOM) Institute of Medicine. Committee on the assessment of asthma and indoor air. Clearing the air: asthma and indoor air exposures. Washington, D.C.: National Academies Press; 2000.
- (USAB) United States Access Board. Access board meeting policy; 2000. (July 26, <http://www.access-board.gov/> (accessed June 3, 2010)).

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.

³⁶ Two-sample t-tests and Chi-Squared tests all yielded p-values greater than 0.70.

- Api AM, Basketter DA, Cadby PA, Cano MF, Ellis G, Gerberick GF, et al. Dermal sensitization quantitative risk assessment (QRA) for fragrance ingredients. *Regul Toxicol Pharmacol* 2008;52(1):3–23.
- Bickers DR, Calow P, Greim HA, Hanifin JM, Rogers AE, Saurat JH, et al. The safety assessment of fragrance materials. *Regul Toxicol Pharmacol* 2003;37(2):218–73.
- Cadby PA, Troy WR, Vey MGH. Consumer exposure to fragrance ingredients: providing estimates for safety evaluation. *Regul Toxicol Pharmacol* 2002;36(3):246–52.
- Caress SM, Steinemann AC. A national population study of the prevalence of multiple chemical sensitivity. *Arch Environ Health* 2004;59(6):300–5.
- Caress SM, Steinemann AC. National prevalence of asthma and chemical hypersensitivity: an examination of potential overlap. *J Occup Environ Med* 2005;47:518–22.
- Cooper SD, Raymer JH, Pellizzari ED, Thomas KW, Castillo NP, Maewall S. Polar organic compounds in fragrances of consumer products. Final Report, Contract # 68-02-4544. Research Triangle Park, NC: US EPA; 1992.
- Cooper SD, Raymer JH, Pellizzari ED, Thomas KW. The identification of polar organic compounds found in consumer products and their toxicological properties. *J Expo Anal Environ Epidemiol* 1995;5(1):57–75.
- Destailats H, Lunden MM, Singer BC, Coleman BK, Hodgson AT, Weschler CJ, et al. Indoor secondary pollutants from household product emissions in the presence of ozone: a bench-scale chamber study. *Environ Sci Technol* 2006;40(14):4421–8.
- Edwards RD, Jurvelin J, Saarela K, Jantunen M. VOC concentrations measured in personal samples and residential indoor, outdoor and workplace microenvironments in EXPOLIS-Helsinki, Finland. *Atmos Environ* 2001a;35:4531–43.
- Edwards RD, Jurvelin J, Koistinen K, Saarela K, Jantunen M. VOC source identification from personal and residential indoor, outdoor and workplace microenvironment samples in EXPOLIS-Helsinki, Finland. *Atmos Environ* 2001b;35:4829–41.
- Edwards RD, Schweizer C, Iacqua V, Lai HK, Jantunen M, Bayer-Oglesby L, et al. Time-activity relationships to VOC personal exposure factors. *Atmos Environ* 2006;40:5685–700.
- Elberling J, Linneberg A, Dirksen A, Johansen JD, Frølund L, Madsen F, et al. Mucosal symptoms elicited by fragrance products in a population-based sample in relation to atopy and bronchial hyper-reactivity. *Clin Exp Allergy* 2005;35(1):75–81.
- Fan Z, Weschler CJ, Han I-K, Zhang J. Co-formation of hydroperoxides and ultra-fine particles during the reactions of ozone with a complex VOC mixture under simulated indoor conditions. *Atmos Environ* 2005;39(28):5171–82.
- Ford RA, Domeyer B, Easterday O, Maier K, Middleton J. Criteria for development of a database for safety evaluation of fragrance ingredients. *Regul Toxicol Pharmacol* 2000;31(2):166–81.
- Givaudan. Flavour + fragrance; 2009 (<http://www.givaudan.com/givcom/> (accessed May 20)).
- Gokhale S, Kohajda T, Schlink U. Source apportionment of human personal exposure to volatile organic compounds in homes, offices and outdoors by chemical mass balance and genetic algorithm receptor models. *Sci Total Environ* 2008;407(1):122–38.
- Jo W-K, Lee J-H, Kim M-K. Head-space, small-chamber and in-vehicle tests for volatile organic compounds (VOCs) emitted from air fresheners for the Korean market. *Chemosphere* 2008;70(10):1827–34.
- Johansen JD. Fragrance contact allergy: a clinical review. *Am J Clin Dermatol* 2003;4(11):789–98.
- Kelman L. Osmophobia and taste abnormality in migraineurs: a tertiary care study. *Headache* 2004;44(10):1019–23.
- Knöppel H, Schauenburg H. Screening of household products for the emission of volatile organic compounds. *Environ Int* 1989;15:413–8.
- Kumar P, Caradonna-Graham VM, Gupta S, Cai X, Rao PN, Thompson J. Inhalation challenge effects of perfume scent strips in patients with asthma. *Ann Allergy Asthma Immunol* 1995;75(5):429–33.
- Kwon KD, Jo WK, Lim H-J, Jeong W-S. Volatile pollutants emitted from selected liquid household products. *Environ Sci Pollut Res* 2008;15(6):521–6.
- MarketResearch.com. Packaged Facts. The U.S. market for household cleaning products. New York: Packaged Facts; 2005 (<http://packagedfacts.com/>).
- MarketResearch.com. Packaged Facts. Laundry care products in the U.S. Rockville, MD: Packaged Facts; 2007 (<http://packagedfacts.com/>).
- Millqvist E, Löwhagen O. Placebo-controlled challenges with perfume in patients with asthma-like symptoms. *Allergy* 1996;51(6):434–9.
- Nazaroff WW, Weschler CJ. Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmos Environ* 2004;38(18):2841–65.
- Opiekun RE, Smeets M, Sulewski M, Rogers R, Prasad N, Vedula U, et al. Assessment of ocular and nasal irritation in asthmatics resulting from fragrance exposure. *Clin Exp Allergy* 2003;33:1256–65.
- Rastogi SC, Heydorn S, Johansen JD, Basketter DA. Fragrance chemicals in domestic and occupational products. *Contact Dermat* 2001;45(4):221–5.
- Rastogi SC, Johansen JD, Bossi R. Selected important fragrance sensitizers in perfumes—current exposures. *Contact Dermat* 2007;56(4):201–4.
- Sack TM, Steele DH, Hammerstrom K, Remmers J. A survey of household products for volatile organic compounds. *Atmos Environ* 1992;26A(6):1063–70.
- Sarwar G, Olson D, Corsi RL, Weschler C. Indoor fine particles: the role of terpene emissions from consumer products. *J Air Waste Manage Assoc* 2004;54(3):367–77.
- Sigma-Aldrich. Flavors and fragrances; 2009 (<http://www.sigmaaldrich.com/life-science/life-science-catalog/product-catalog.html?TablePage=12916829> (accessed May 20)).
- Singer BC, Destailats H, Hodgson AT, Nazaroff WN. Cleaning products and air fresheners: emissions and resulting concentrations of glycol ethers and terpenoids. *Indoor Air* 2006;16(3):179–91.
- Smith LW. The scientific basis for sound decisions on fragrance material use. *Regul Toxicol Pharmacol* 2003;37(2):172.
- Smith LW. More recent studies on fragrances. *Environ Health Perspect* 2004;112(15):A865.
- Smith LW, Rogers RE, Black MS, Isola DA. Exposure characterizations of three fragranced products. *Toxicol Appl Pharmacol* 2004;197(3):189.
- Steinemann AC. Fragranced consumer products and undisclosed ingredients. *Environ Impact Assess Rev* 2009;29(1):32–8.
- Steinemann A, Walsh N. Environmental laws and exposure analysis. In: Ott W, Steinemann A, Wallace L, editors. *Exposure analysis*. Boca Raton: CRC Press; 2007.
- Takasago. Aroma chemical compendium; 2009 (<http://www.takasago.com/aroma-chemicals/body.htm> (accessed May 20)).
- Wainman T, Zhang J, Weschler CJ, Liou PJ. Ozone and limonene in indoor air: a source of submicron particle exposure. *Environ Health Perspect* 2000;108(12):1139–45.
- Wallace LA. The TEAM study: summary and analysis: volume I. EPA 600/6-87/002a. NTIS PB 88-100060. Washington, DC: U.S. EPA; 1987.
- Wallace LA. Assessing human exposure to volatile organic compounds. In: Spengler JD, McCarthy JF, Samet J, editors. *Indoor air quality handbook*. New York: McGraw-Hill; 2001. (Chapter 33).
- Wallace LA, Nelson WC, Pellizzari E, Raymer JH, Thomas KW. Identification of polar volatile organic compounds in consumer products and common microenvironments. Paper #91-62.4 presented at the 84th Annual Meeting of the Air and Waste Management Association, Vancouver, BC; 1991. (June).