



Fragranced consumer products and effects on asthmatics: an international population-based study

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Abstract

Asthma is an international concern, with risks linked to air pollutants. Fragranced consumer products, such as air fresheners and cleaning supplies, have been associated with health problems such as asthma attacks and breathing difficulties. This study investigates the health and societal effects of fragranced products on asthmatics in four countries: United States, Australia, United Kingdom, and Sweden. Nationally representative population surveys ($n = 1137$; 1098; 1100; 1100) found that, across the four countries, 26.0% of adults ($n = 1151$) are asthmatic, reporting medically diagnosed asthma (15.8%), an asthma-like condition (11.1%), or both. Among these asthmatics, 57.8% report adverse health effects, including asthma attacks (25.0%), respiratory problems (37.7%), and migraine headaches (22.6%), from exposure to fragranced products. In particular, 36.7% of asthmatics report health problems from air fresheners or deodorizers, 18.1% from the scent of laundry products coming from a dryer vent, 32.9% from being in a room cleaned with scented products, 38.7% from being near someone wearing a fragranced product, and 37.5% from other types of fragranced products. For 24.1% of asthmatics, health problems from fragranced products are potentially disabling. Further, 20.6% of asthmatics have lost workdays or lost a job, in the past year, due to fragranced product exposure in the workplace. Fragrance-free environments received widespread support. More than twice as many individuals, both asthmatics as well as non-asthmatics, would prefer that workplaces, health care facilities and professionals, airplanes, and hotels were fragrance-free rather than fragranced. This study provides evidence that asthmatics can be profoundly, adversely, and disproportionately affected by exposure to fragranced consumer products. Moreover, the study points to a relatively straightforward and cost-effective approach to reduce risks; namely, to reduce exposure to fragranced products.

Keywords Asthma · Asthma-like condition · Asthmatic · Fragranced consumer products · Indoor air quality · Fragrance · Health effects · Volatile organic compounds

Introduction

Fragranced consumer products—such as air fresheners, cleaning supplies, laundry detergents, scented candles, essential oils, colognes, soaps, and personal care products—are

widely used throughout society (Steinemann 2016). Fragranced products emit numerous volatile organic compounds (VOCs) including asthmagens (Weinberg et al. 2017) and hazardous air pollutants (e.g., Nazaroff and Weschler 2004). Fragranced products have been implicated as an important source of human exposure to VOCs (e.g., Hoang et al. 2017; Gokhale et al. 2008; Wallace 2001), as well as indoor air pollution (e.g., Geiss et al. 2011; Edwards et al. 2001; Goodman et al. 2017) and urban outdoor air pollution (McDonald et al. 2018).

A “fragranced consumer product” (or “fragranced product”) is a product that contains an added fragrance or that is largely comprised of fragrance (Steinemann 2016). A single “fragrance” in a product is typically a complex mixture of dozens of compounds (Steinemann 2015), many derived from petrochemicals (Sell 2006). However, no law in any country requires full disclosure of all ingredients in a fragrance. Further, no law requires full disclosure of all ingredients in a

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consumer product (other than for foods, drugs, and cosmetics). Thus, consumers have limited information on fragrance ingredients as well as whether a product even contains a fragrance (Lunny et al. 2017; Steinemann 2009).

Exposure to fragranced products has been associated with adverse health effects in the general population and in vulnerable sub-populations. Studies in the United States (US), Australia (AU), United Kingdom (UK), and Sweden (SE) found that, on average, 32.2% of the general population (34.7%, 33.0%, 27.8%, and 33.1%, respectively) report health problems when exposed to fragranced products such as air fresheners, laundry supplies, cleaning products, personal care products, and household items (Steinemann 2016, 2017a, 2018a, b). Health problems include respiratory difficulties, migraine headaches, asthma attacks, mucosal symptoms, skin rashes, and neurological problems, among others. Among vulnerable sub-populations, 75.8% of individuals with autism (83.7%, 82.9%, 84.6%, and 51.8%, respectively) and 81.3% with chemical sensitivity (78.9%, 82.1%, 77.3%, and 86.9%, respectively) report adverse health effects from exposure to fragranced products (Steinemann 2018d, 2019).

Relatively little prior population-based research has investigated links between fragranced products and asthma. In two national studies, upon which this international study builds, 64.3% and 55.6% of asthmatics in the US and AU, respectively, report adverse health effects from fragranced products (Steinemann 2018c; Steinemann et al. 2018). Two studies in the US, conducted in 2002–2003 and 2005–2006, found that 29.7% and 37.2%, respectively, of asthmatics report adverse health effects from air fresheners or deodorizers (Caress and Steinemann 2009). A study of workers in California found that 3.8% of 7163 confirmed work-related asthma cases from 1993 to 2012 were associated with fragranced product exposure (Weinberg et al. 2017).

This present study investigates the effects of exposure to fragranced products on asthmatic adults in four countries (US, AU, UK, SE). It assesses the types and severity of health effects associated with different types of fragranced product exposures; societal effects such as access to public places, lost workdays and lost jobs; and preferences for fragrance-free environments. It extends the prior national studies of asthmatics in the US and AU with results from studies in the UK and SE, offering greater breadth and depth of analysis. Results from this study reveal important and under-explored associations between fragranced products and asthmatics and suggest a relatively straightforward way to reduce adverse effects by reducing exposure.

Methods

Nationally representative population-based cross-sectional studies, using the same survey instrument, were

conducted of adults ages 18–65 in the United States, Australia, United Kingdom, and Sweden. Sample populations were representative of the general populations according to age, gender, and region ($n = 1137$; 1098; 1100; 1100; respectively; confidence limit = 95%, margin of error = 3% for all studies). The surveys drew upon large web-based panels (with over 5,000,000; 200,000; 900,000; 60,000 people, respectively) held by Survey Sampling International (SSI). For the panels, SSI uses multi-source samples to develop a blend that reflects the heterogeneity of the study population. For the surveys, recruitment followed a three-step randomization process to identify potential participants [see Electronic Supplementary Materials ([ESM-Survey Methods](#) and [ESM-SSI Methodologies](#))]. The survey instrument, a questionnaire in each country's native language, was developed and tested over a 2-year period before full implementation in June 2016 (US, AU, UK) and June 2017 (SE). The survey response rate was 94%, 93%, 97%, and 92% (respectively), and all responses were anonymous. The research study received ethics approval from the University of Melbourne. Survey methods are detailed in the Electronic Supplementary Material ([ESM-Survey Methods](#)).

Descriptive statistics and cross-tabulations determined percentages according to each response and sub-population; see Electronic Supplementary Material ([ESM-Data](#)). Prevalence odds ratios (PORs) measured the strength of associations to determine whether one sub-population is proportionally more affected than another. Chi-squared analyses compared proportions among countries to determine whether a statistically significant difference exists. All POR and chi-squared analyses were performed using a 95% confidence interval (CI) or a 95% confidence level, respectively.

To promote comparability, the survey replicated questions from previous studies of asthma/asthma-like conditions and fragrance sensitivity (Steinemann 2016, 2017a, 2018a, b, c, 2019; Steinemann et al. 2018; Caress and Steinemann 2009), as follows.

For asthma/asthma-like conditions, the survey asked, “Has a doctor or health care professional ever told you that you have asthma or an asthma-like condition?” If the respondent answered yes, the survey then asked to specify whether “asthma” or an “asthma-like condition” or both.

For fragrance sensitivity, defined as adverse effects from exposure to fragranced consumer products (Caress and Steinemann 2009), the survey asked, “Do you experience any health problems when exposed to (fragranced product)?” If the respondent answered yes, the survey then asked the respondent to specify which health problems they experienced. An individual was considered to characterize fragrance sensitivity if they reported one or more types of health problems from

exposure to one or more types of fragranced consumer products.

Fragranced products were categorized as follows: (a) air fresheners and deodorizers (e.g., sprays, solids, oils, disks), (b) personal care products (e.g., soaps, hand sanitizer, lotions, deodorant, sunscreen, shampoos), (c) cleaning supplies (e.g., all-purpose cleaners, disinfectants, dishwashing soap), (d) laundry products (e.g., detergents, fabric softeners, dryer sheets), (e) household products (e.g., scented candles, restroom paper, trash bags, baby products), (f) fragrance (e.g., perfume, cologne, after-shave, essential oils), and (g) other.

Exposure contexts included the following: air fresheners or deodorizers used within indoor environments, scented laundry products coming from a dryer vent, being in a room after it was cleaned with scented cleaning products, being near someone wearing a fragranced product, and exposure to other types of fragranced consumer products.

Health effects were categorized as follows: (a) migraine headaches, (b) asthma attacks, (c) neurological problems (e.g., dizziness, seizures, head pain, fainting, loss of coordination), (d) respiratory problems (e.g., difficulty breathing, coughing, shortness of breath), (e) skin problems (e.g., rashes, hives, red skin, tingling skin, dermatitis), (f) cognitive problems (e.g., difficulties thinking, concentrating, or remembering), (g) mucosal symptoms (e.g., watery or red eyes, nasal congestion, sneezing), (h) immune system problems (e.g., swollen lymph glands, fever, fatigue), (i) gastrointestinal problems (e.g., nausea, bloating, cramping, diarrhea), (j) Cardiovascular problems (e.g., fast or irregular heartbeat, jitteriness, chest discomfort), (k)

musculoskeletal problems (e.g., muscle or joint pain, cramps, weakness), and (l) other.

Societal effects included the following: ability to access restrooms, businesses, and other locations that use air fresheners or other fragranced products; loss of workdays or lost jobs due to illness from fragranced product exposure in the workplace; disabling health effects from exposure to fragranced products; and preferences for fragrance-free workplaces, health care facilities, health care professionals, airplanes, and hotels.

Results

Main findings are provided in this section, with summaries in Tables 1, 2, and 3. Complete data and statistical analyses for each country individually, and across the four countries, are provided as Electronic Supplementary Material ([ESM-Data](#)).

Study populations, prevalence, and fragranced product use and exposure

Of the general population surveyed in four countries, 26.0% of adults ($n = 1151$) are asthmatic (26.8% US; 28.5% AU; 25.3% UK; 23.2% SE), reporting medically diagnosed asthma (15.8%), an asthma-like condition (11.1%), or both (Table 1). Across the four countries, no statistically significant difference was found in the prevalence of asthma/asthma-like conditions ($p = 0.087$, chi-square test).

Among asthmatics, 99.8% are exposed to fragranced products at least once a week from their own use (99.1%), others' use (93.2%), or both (see [ESM-Data](#)). Among non-asthmatics,

Table 1 Study populations: asthmatic and non-asthmatic adults in the United States (US), Australia (AU), United Kingdom (UK), and Sweden (SE)

	US	AU	UK	SE	Total/average %
Total (n) general population	1137	1098	1100	1100	4435
Asthmatic (asthma/asthma-like condition)	305	313	278	255	1151
	26.8%	28.5%	25.3%	23.2%	26.0%
Asthma	173	176	188	164	701
	15.2%	16.0%	17.1%	14.9%	15.8%
Asthma-like condition	142	151	99	100	492
	12.5%	13.8%	9.0%	9.1%	11.1%
Non-asthmatic	832	785	822	845	3284
	73.2%	71.5%	74.7%	76.8%	74.1%
Not asthma/asthma-like condition	811	740	791	804	3146
	97.5%	94.3%	96.2%	95.1%	95.8%
Do not know/not sure	19	43	30	36	128
	2.3%	5.5%	3.6%	4.3%	3.9%
Decline to answer	2	2	1	5	10
	0.2%	0.3%	0.1%	0.6%	0.3%

98.9% are exposed to fragranced products at least once a week from their own use (98.0%), others' use (89.7%), or both. Across the four countries, no statistically significant difference was found in the use and exposure to fragranced products among asthmatics ($p = 0.99$, chi-square test) or between asthmatics and non-asthmatics ($p = 0.92$, chi-square test).

Health problems reported from fragranced consumer products

Among asthmatics, 57.8% report fragrance sensitivity (64.3% US, 55.6% AU, 54.0% UK, 57.3% SE); that is, adverse health effects from exposure to fragranced products. The most common adverse health effects were respiratory problems (37.7%), mucosal symptoms (25.4%), asthma attacks (25.0%), migraine headaches (22.6%), and skin problems (17.1%) (Table 2). Among non-asthmatics, 23.1% report fragrance sensitivity (Table 2). Across all types of health effects, asthmatics are proportionally more affected than non-asthmatics (POR 4.56; 95% CI 3.96–5.26).

Severity of health effects from exposure to fragranced products was investigated using criteria for disability according to each country's legislation (ADAAA 2008; DDA 1992; EA 2010; DA 2008). Among all asthmatics, 24.1% across the four countries (40.3% US, 15.0% AU, 20.1% UK, 20.8% SE)

report that effects from fragranced products are potentially disabling, which represents 40.9% of fragrance-sensitive asthmatics (Table 2 and [ESM-Data](#)). Among non-asthmatics, 6.4% report potentially disabling effects (Table 2). While both asthmatics and non-asthmatics can be severely affected by fragranced products, asthmatics are proportionally more affected (POR 4.72; 95% CI 4.09–5.45).

Fragranced product exposures, societal access, and workplace effects

Among asthmatics, 36.7% report health problems from air fresheners and deodorizers, 18.1% from the scent of laundry products coming from a dryer vent, 32.9% from being in a room recently cleaned with scented products, 38.7% from being near someone wearing a fragranced product, and 37.5% from other types of fragranced consumer products (see Table 3).

Fragranced product exposures are associated with loss of societal access: 26.4% of asthmatics are unable or reluctant to use the restrooms in a public place if it has an air freshener, deodorizer, or scented product; 21.9% are unable or reluctant to wash their hands with soap in a public place if the soap is fragranced; 31.6% enter a business and then want to leave as quickly as possible if they smell air fresheners or a fragranced

Table 2 Types of health problems from exposure to fragranced consumer products for asthmatics and non-asthmatics

	Asthmatics	Non-asthmatics
Total (<i>n</i>) asthmatic/non-asthmatic individuals	1151	3284
Health problems from fragranced products (<i>n</i> , %) (fragrance sensitivity)	666 57.8%	760 23.1%
Asthmatic individuals: US (64.3%), AU (55.6%), UK (54.0%), SE (57.3%)		
Non-asthmatic individuals: US (23.8%), AU (23.9%), UK (19.0%), SE (25.8%)		
Types of health problems from exposure to fragranced consumer products:		
<i>Migraine headaches</i>	22.6%	9.1%
<i>Asthma attacks</i>	25.0%	0.7%
<i>Neurological problems</i> (e.g., dizziness, seizures, head pain, fainting, loss of coordination)	10.2%	3.3%
<i>Respiratory problems</i> (e.g., difficulty breathing, coughing, shortness of breath)	37.7%	9.4%
<i>Skin problems</i> (e.g., rashes, hives, red skin, tingling skin, dermatitis)	17.1%	6.3%
<i>Cognitive problems</i> (e.g., difficulties thinking, concentrating, or remembering)	9.8%	2.4%
<i>Mucosal symptoms</i> (e.g., watery or red eyes, nasal congestion, sneezing)	25.4%	9.0%
<i>Immune system problems</i> (e.g., swollen lymph glands, fever, fatigue)	6.5%	1.2%
<i>Gastrointestinal problems</i> (e.g., nausea, bloating, cramping, diarrhea)	8.6%	2.2%
<i>Cardiovascular problems</i> (e.g., fast or irregular heartbeat, jitteriness, chest discomfort)	7.9%	1.5%
<i>Musculoskeletal problems</i> (e.g., muscle or joint pain, cramps, weakness)	6.5%	1.1%
<i>Other</i>	1.6%	2.1%
Health problems from fragranced consumer products are potentially disabling	24.1%	6.4%
Asthmatics: US (40.3%), AU (15.0%), UK (20.1%), SE (20.8%)		
Non-asthmatics: US (8.7%), AU (6.0%), UK (6.8%), SE (41%)		

Table 3 Health problems, societal access, and workplace effects from exposure to fragranced consumer products for asthmatics and non-asthmatics

	Asthmatics	Non-asthmatics
Total (<i>n</i>) asthmatic/non-asthmatic individuals	1151	3284
Health problems from fragranced products (<i>n</i> , %) (fragrance sensitivity)	666 57.8%	760 23.1%
<i>Health problems from exposure to:</i>		
Air fresheners or deodorizers	36.7%	10.6%
Scent of laundry products from a dryer vent	18.1%	3.9%
Room cleaned with scented products	32.9%	9.6%
Someone wearing a fragranced product	38.7%	13.6%
Any other type of fragranced consumer product	37.5%	11.9%
<i>Societal access and workplace effects:</i>		
Unable to use restrooms in public place because of air freshener, deodorizer, or scented product	26.4%	8.7%
Unable to wash hands in public place because of fragranced soap	21.9%	6.3%
Enter but then leave a business quickly because of fragranced product	31.6%	11.8%
Prevented from going to some place because of fragranced product	32.9%	9.9%
Lost workdays or lost a job, in the past year, due to fragranced product exposure in workplace	20.6%	4.8%
Supportive of fragrance-free policy in the workplace	56.7%	44.7%
Prefer fragrance-free health care facilities and professionals	62.3%	47.5%
Prefer airplane without fragranced air	68.8%	63.3%
Prefer hotel without fragranced air	65.8%	58.9%

product; and 32.9% have been prevented from going someplace because they would be exposed to a fragranced product that would make them sick (see Table 3).

Exposures are also associated with lost workdays and lost jobs: 20.6% of asthmatics have lost workdays or lost a job, in the past year, due to illness from fragranced product exposure in the workplace. Accordingly, fragrance-free workplaces and other indoor environments receive a strong majority of support among both asthmatic and non-asthmatics, as detailed below (see Table 3).

For fragrance-free workplace policies: Among asthmatics, 56.7% would support a fragrance-free policy in the workplace (compared to 17.7% that would not). Among non-asthmatics, 44.7% would support a fragrance-free workplace (compared with 21.4% that would not). Thus, over three times as many asthmatics, and two times as many non-asthmatics, would support fragrance-free workplace policies (than not).

For health care facilities and health care professionals: Among asthmatics, 62.3% would prefer that health care facilities and professionals were fragrance-free (compared to 18.3% that would not). Among non-asthmatics, 47.5% would prefer that health care facilities and professionals were fragrance-free (compared to 23.4% that would not). Thus, over three times as many asthmatics, and two times as many non-asthmatics, would prefer fragrance-free health care facilities and health care professionals (than not).

For airplane travel: Among asthmatics, if given a choice between flying on an airplane with or without fragranced air

pumped throughout the passenger cabin, 68.8% would choose an airplane without fragranced air (compared to 17.3% with fragranced air). Among non-asthmatics, 63.3% would choose an airplane without fragranced air (compared to 15.7% with fragranced air). Thus, nearly four times as many asthmatics as well as non-asthmatics would choose an airplane without fragranced air (than with fragranced air).

For hotels: Among asthmatics, if given a choice between staying in a hotel with or without fragranced air, 65.8% would choose a hotel without fragranced air (compared to 22.7% with fragranced air). Among non-asthmatics, 58.9% would choose a hotel without fragranced air (compared to 21.9% with fragranced air). Thus, nearly three times as many asthmatics as well as non-asthmatics would choose a hotel without fragranced air (than with fragranced air).

Study strengths include the following: (a) sample populations in each country were statistically representative of age, gender, and region; (b) respondents were randomly recruited from large web-based panels developed from multiple sources to reflect population characteristics; and (c) the survey employed questions from large national studies previously conducted and published to promote replicability and comparability.

Study limitations include the following: (a) only adults ages 18–65 were included in the survey, which excludes other age groups; (b) the survey relied on self-reported data; however, self-report is a widely accepted method for survey research; (c) the cross-sectional design of the survey represents

data from only one point in time; and (d) all possible fragranced products and health effects were not included, although the relatively low percentages of responses in the “other” categories indicate the survey captured the primary products and effects.

Discussion

This study adds to the growing scientific evidence that exposure to fragranced consumer products is associated with adverse health and societal effects, especially in vulnerable populations such as asthmatics.

For instance, as estimated across the four countries (USCB 2016; ABS 2016; ONS 2016; SCB 2017), over 10 million adults experience asthma attacks from exposure to air fresheners. In addition, for over 20 million asthmatics, illness from exposure to fragranced products in the workplace was associated with lost workdays and lost jobs. Further, for over 24 million asthmatics, health problems from exposure are potentially disabling.

Given that fragranced products are reported to trigger asthma attacks in an estimated 25% of asthmatics, and additional types of health problems in more than 50% of asthmatics, reducing exposure would appear to be a logical, cost-effective, and medically effective approach to asthma control.

To that end, fragrance-free products offer practical alternatives and can reduce fragrance compound emissions (Goodman et al. 2018). Further, as this study demonstrated, fragrance-free policies and fragrance-free environments are preferred by a majority of the population, both asthmatics and non-asthmatics.

To assist in reducing exposure, an important step would be the required listing of “fragrance” on the label for all types of consumer products (not only for foods, drugs, and cosmetics). Analysis of fragranced consumer products found that 2/3 did not disclose that the product contained fragrance (Steinemann 2015). Further, an “unscented” product may not be “fragrance-free”; it may still contain fragrance but with a masking fragrance to cover the scent (Steinemann 2015).

A further step would be the disclosure of fragrance ingredients. Analysis of fragranced consumer products found that most ingredients (over 90%), even potentially hazardous compounds, were not listed on the product label, safety data sheet, or elsewhere (Nematollahi et al. 2018a, b; Steinemann 2015, 2017b). One approach is the listing of certain fragrance ingredients such as allergens (e.g., EU 2009). However, allergens may not address all major health effects of concern associated with fragranced consumer products, as this study demonstrates.

It should not be surprising that fragranced consumer products can be associated with asthmatic exacerbations and respiratory difficulties, as noted by Weinberg et al. (2017). What is

surprising, however, is that a seemingly obvious and effective approach—reducing exposure to reduce adverse effects—is not more widely recognized and implemented. However, results from this study may provide the foundations for more effective approaches to reduce the burden of asthma.

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Compliance with ethical standards The research study received ethics approval from the University of Melbourne. Survey methods are detailed in the Electronic Supplementary Material ([ESM-Survey Methods](#)).

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References

- Australian Bureau of Statistics (ABS) (2016) Census Data for Australia (Estimated 2016 population of adults ages 18–65 is 14,507,551). http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/036?opendocument. Accessed 6 April 2019
- Americans with disabilities act amendments act of 2008 (ADAAA) (2008) 42 U.S. Code § 12,102 - Definition of disability (Pub. L. 101–336, § 3, July 26, 1990, 104 Stat. 329; Pub. L. 110–325, § 4(a), Sept. 25, 2008, 122 Stat. 3555.) Available at: <https://www.law.cornell.edu/uscode/text/42/12102>. Accessed 6 April 2019
- Caress SM, Steinemann AC (2009) Prevalence of fragrance sensitivity in the American population. *J Environ Health* 71(7):46–50
- Disability Discrimination Act (DDA) (1992) Australian Government. Act No. 135 of 1992. <https://www.legislation.gov.au/Series/C2004A04426>. Accessed 6 April 2019
- Discrimination Act (Diskrimineringslagen) (DA) (2008) SFS No: 2008:567, Section 5:4. Definition of disability. https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/diskrimineringslag-2008567_sfs-2008-567; https://www.government.se/contentassets/6732121a2cb54ee3b21da9c628b6bdc7/oversattning-diskrimineringslagen_eng.pdf. Accessed 6 April 2019
- Edwards RD, Jurvelin J, Koistinen K, Saarela K, Jantunen M (2001) VOC source identification from personal and residential indoor, outdoor and workplace microenvironment samples in EXPOLIS-Helsinki, Finland. *Atmos Environ* 35:4829–4841
- Equality Act (EA) (2010) Chapter 15. Parliament of the United Kingdom. https://www.legislation.gov.uk/ukpga/2010/15/pdfs/ukpga_20100015_en.pdf. Accessed 6 April 2019
- European Union (EU) (2009) Regulation (EC) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on

- Cosmetic Products [2009] OJ L 342/59, art 19(g) ('EU Regulations').
- Geiss O, Giannopoulos G, Tirendi S, Barrero-Moreno J, Larsen BR, Kotzias D (2011) The AIRMEX study - VOC measurements in public buildings and schools/kindergartens in eleven European cities: statistical analysis of the data. *Atmos Environ* 45(22):3676–3684
- Gokhale S, Kohajda T, Schlink U (2008) 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* 407(1):122–138
- Goodman NB, Steinemann A, Wheeler AJ, Paevere PJ, Cheng M, Brown SK (2017) Volatile organic compounds within indoor environments in Australia. *Build Environ* 122:116–125
- Goodman NB, Wheeler AJ, Paevere PJ, Agosti G, Nematollahi N, Steinemann A (2018) Emissions from dryer vents during use of fragranced and fragrance-free laundry products. *Air Qual Atmos Health* (online 28 Nov 2018).
- Hoang T, Castorina R, Gaspar F, Maddalena R, Jenkins PL, Zhang Q, McKone TE, Benfenati E, Shi AY, Bradman A (2017) VOC exposures in California early childhood education environments. *Indoor Air* 27(3):609–621
- Lunny S, Nelson R, Steinemann A (2017) Something in the air but not on the label: a call for increased regulatory ingredient disclosure for fragranced consumer products. *UNSW Law Journal* 40(4):1366–1391
- McDonald BC, de Gouw JA, Gilman JB, Jathar SH, Akherati A, Cappa CD et al (2018) Volatile chemical products emerging as largest petrochemical source of urban organic emissions. *Science* 359(6377):760–764
- Nazaroff WW, Weschler CJ (2004) Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmos Environ* 38:2841–2865
- Nematollahi N, Doronila A, Mornane P, Duan A, Kolev SD, Steinemann A (2018a) Volatile chemical emissions from fragranced baby products. *Air Qual Atmos Health* 11(7):949–954
- Nematollahi N, Kolev SD, Steinemann A (2018b) Volatile chemical emissions from essential oils. *Air Qual Atmos Health* 11(8):949–954
- Office for National Statistics, United Kingdom (ONS) (2016) Population estimates. Analysis tool. (estimated 2016 population of adults ages 18–65 is 35,395,854.) <https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates>. Accessed 6 April 2019
- Sell C (ed) (2006) *The chemistry of fragrances: from perfumer to consumer*, 2nd edn. The Royal Society of Chemistry, Cambridge
- Statistics Sweden, Statistiska centralbyråns (SCB) (2017) Sweden Government Offices. (Estimated 2017 population of adults ages 18–65 is 5,992,498). <http://www.scb.se/en/finding-statistics/statistics-by-subject-area/population/population-composition/population-statistics/pong/tables-and-graphs/yearly-statistics%2D%2Dthe-whole-country/summary-of-population-statistics/>. Accessed 6 April 2019
- Steinemann AC (2009) Fragranced consumer products and undisclosed ingredients. *Environ Impact Assess Rev* 29(1):32–38
- Steinemann A (2015) Volatile emissions from common consumer products. *Air Qual Atmos Health* 8(3):273–281
- Steinemann A (2016) Fragranced consumer products: exposures and effects from emissions. *Air Qual Atmos Health* 9(8):861–866
- Steinemann A (2017a) Health and societal effects from fragranced consumer products. *Prev Med Rep* 5:45–47
- Steinemann A (2017b) Ten questions concerning air fresheners and indoor built environments. *Build Environ* 111:279–284
- Steinemann A (2018a) Fragranced consumer products: sources of emissions, exposures, and health effects in the United Kingdom. *Air Qual Atmos Health* 11(3):253–258
- Steinemann A (2018b) Exposures and effects from fragranced consumer products in Sweden. *Air Qual Atmos Health* 11(5):485–491
- Steinemann A (2018c) Fragranced consumer products: effects on asthmatics. *Air Qual Atmos Health* 11(1):3–9
- Steinemann A (2018d) Fragranced consumer products: effects on autistic adults in the United States, Australia, and United Kingdom. *Air Qual Atmos Health* 1–6.
- Steinemann A (2019) International Prevalence of Chemical Sensitivity, Co-Prevalence with Asthma and Autism, and effects from fragranced consumer products. *Air Qual Atmos Health* (accepted 23 Jan 2019).
- Steinemann A, Wheeler AJ, Larcombe A (2018) Fragranced consumer products: effects on asthmatic Australians. *Air Qual Atmos Health* 11(4):365–371
- United States Census Bureau (USCB) (2016) Quick facts. Population; age and sex. (Estimated 2016 population of adults ages 18–65 is 199,864,867) Available at: <https://www.census.gov/quickfacts/fact/table/US/AGE275210#viewtop>. Accessed 6 April 2019
- Wallace LA (2001) Assessing human exposure to volatile organic compounds. In: Spengler JD, McCarthy JF, Samet J (eds) *Indoor air quality handbook*. McGraw-Hill, New York Chapter 33
- Weinberg JL, Flattery J, Harrison R (2017) Fragrances and work-related asthma—California surveillance data, 1993–2012. *J Asthma* 1–10

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