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10 Questions

Ten questions concerning air fresheners and indoor built environments

Anne Steinemann [a, b, c, *]

[a] Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, Victoria 3010, Australia
[b] College of Science, Technology and Engineering, James Cook University, Townsville, Queensland 4811, Australia
[c] Climate, Atmospheric Sciences, and Physical Oceanography, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093, USA

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ABSTRACT

Air fresheners are pervasive within indoor built environments, such as workplaces, schools, housing, transportation, hotels, hospitals, care facilities, and a range of private and public buildings. Air fresheners are designed to impart an aroma to the air environment or to mask odors, with the intent of creating a pleasing indoor space. However, despite the intent, air fresheners can emit and generate a range of potentially hazardous air pollutants that can impair air quality. Even so-called green and organic air fresheners can emit hazardous air pollutants. Air freshener ingredients are largely unknown and undisclosed, owing to regulatory protections on consumer product ingredients and on fragrance formulations. In studies, fewer than ten percent of all volatile ingredients are typically disclosed on air freshener labels or material safety data sheets. From an indoor air quality perspective, air fresheners have been indicated as a primary source of volatile organic compounds within buildings. From a health perspective, air fresheners have been associated with adverse effects, such as migraine headaches, asthma attacks, mucosal symptoms, infant illness, and breathing difficulties. This article investigates the seeming paradox that products designed to improve the indoor environment can pose unintended and unknown risks. It examines the science, health, and policy perspectives, and provides recommendations and research directions.

1. Ten questions

1.1. What are air fresheners?

Air fresheners are consumer products that emit a fragrance to provide an aroma to a space, to mask an odor, or both. Air fresheners come in numerous versions, including sprays, gels, oils, liquids, solids, plug-ins, hanging disks, beads, potpourri, wick diffusers, and scented candles; in active or passive forms; and with instant, intermittent, or continuous release. Air fresheners also include so-called air care, deodorizer, odor control and neutralizer products. In addition to site-specific units or portable products, air fresheners can include scented air systems, which deliver fragrance throughout a space, such as by connecting a fragrance diffuser to the heating, ventilation, and air conditioning system. In this paper, air fresheners are considered as products designed to impart an aromatic fragrance or a masking fragrance into the air; they are not considered to include air cleaning devices designed to filter or purify the air.

1.2. Where are air fresheners used?

Air fresheners are used throughout society, by individuals, industries, and institutions. Typical indoor environments with air fresheners include the following: buildings and facilities such as offices, schools, hospitals, churches, theaters, stores, hotels, health clubs, restaurants, and restrooms; transportation such as airplanes, airports, cars, taxis, buses, trains, terminals, and boats; residences and care facilities, including homes, apartments, homeless shelters, detention centers, elder care and child care facilities; and others.

The global market for air fresheners exceeds US $10 billion, and is increasing in most countries [17,19]. Europe is the largest market, and Asia is the fastest growing market. For instance, air freshener

* Department of Infrastructure Engineering, Melbourne School of Engineering, The University of Melbourne, Melbourne, Victoria 3010, Australia.
E-mail address: anne.steinemann@unimelb.edu.au.

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usage is increasing by as much as 8.8% every year in Korea [24].

Of the general population surveyed in the US, 72.8% use air fresheners and deodorizers at least once a week, and 57.9% are exposed to air fresheners and deodorizers from others' use at least once a week [39]. An earlier report indicated that air fresheners are used in nearly 75% of US households [31]. In a European population survey, air fresheners (spray, electric, and passive) are used by 39%, 40%, and 30% (respectively) of the surveyed population at least once a week in homes, and by 94%, 92%, 89% (respectively) at least once a month in homes [9].

1.3. What do air fresheners emit?

Air fresheners emit over 100 different chemicals, including volatile organic compounds (terpenes such as limonene, alpha-pinene, and beta-pinene; terpenoids such as linalool and alpha-terpineol; ethanol, formaldehyde, benzene, toluene, and xylene) and semi-volatile organic compounds (such as phthalates) [25,29,40,46].

Air freshener emissions can also react with indoor oxidants, such as ozone (O3), hydroxyl radicals (OH), and nitrate radicals (NO3), to generate a range of oxidation products [29,35]. For instance, primary emissions such as terpenes can readily react with ozone to generate secondary pollutants such as formaldehyde and acetaldehyde, glycol ethers, free radicals (such as hydroperoxy and alkyl peroxy radicals), and ultrafine particles. Factors that influence emissions of secondary pollutants include ingredient composition, ingredient concentrations, reactive chemistry, and product usage [29].

Emissions from air freshener products have been studied around the world (e.g., [5,23,35,40,43,45,46]. Of the studies that examined multiple types of air fresheners (e.g., sprays, gels, solids, disks, oils, cartridges, diffusers, evaporators; both active and passive), results indicate that all types of air fresheners have the potential to emit high concentrations of volatile organic compounds. The composition of the fragrance mixture is likely more influential on emissions than the type of delivery mechanism [40,46].

Given the enumerable different air freshener types, brands, and ingredient compositions, as well as protections on ingredient disclosure, a complete taxonomy of emissions from air fresheners would be interesting although practically infeasible. Nonetheless, results from selected studies are provided to characterize typical product emissions and rates.

In chamber studies of air fresheners in Germany [46], found the highest emissions rates after 1 h (μg/unit h) of the following compounds: ethanol, 35,532; dipropylene glycol mono methyl ether acetate, 12,337; limonene, 9132; 2-propanol 5690; 3-methoxy-3-methyl-1-butanol, 4763; benzyl acetate, 3920; dihydromyrcenol, 3155; iso-alkanes, 3110; linalool, 2994; linalyl acetate, 2711; gamma-terpinene, 2688; dipropylene glycol isomers, 2529; myrcene 1679; and beta-pinene, 1391. Of these, limonene and linalool are listed as potential allergens under [16].

In this same study [46], the most common VOCs emitted (in at least half of the products) were the following: limonene, linalool, myrcene, beta-pinene, alpha-pinene, linalyl acetate, dihydromyrcenol, geranyl acetate, and 4-methoxy-benzaldehyde. Thus, the compounds with the highest emissions rates (over 1000 μg/unit h) and most common in the products were limonene, linalool, myrcene, beta-pinene, linalyl acetate, and dihydromyrcenol.

In a study of VOC emissions from air fresheners in the US, including sprays, gels, solids, disks, and oils [40], the most common VOCs (in at least half of the products) were the following: limonene; acetone; 2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal 1); alpha-pinene; beta-pinene; 1-butanol, 3-methyl-, acetate; 2,4-dimethyl-3-cyclohexene-1-carboxaldehyde (Triplal extra); beta-phellandrene; carene isomer; ethyl butanoate; o, m, or p-cymene; ethanol. Of all VOCs emitted, approximately one-fourth are classified as potentially toxic or hazardous under one or more federal laws in the US, and all air fresheners tested emitted one or more of these compounds.

In a study of air fresheners in Korea [23], found the most common VOCs (in at least half the products) were toluene, bis(-trimethylsilyl) acetylene, benzene, hexamethylcyclotrisiloxane, pentadecane, ethanol, ethyl benzene, limonene, and m,p-xylene. The highest emission rate was limonene (1560 μg/h).

In a study of SVOC emissions from air fresheners in the US, including “all-natural” and “unscented” varieties, 12 of the 14 products tested emitted phthalates. Of these, 10 products emitted at least 1 ppm and up to 7307 ppm of phthalates [31].

1.4. How do air freshener emissions affect the indoor environment?

Air fresheners can contribute to indoor hazardous air pollutants, both through direct emissions and secondary reaction products (e.g., [4,20,22,25,27,28,32,46]. Within buildings and other indoor environments, the use of air fresheners has a strong association with high indoor levels of terpenes, benzene, toluene, ethylbenzene, m,p-xylene, and total volatile organic compounds (e.g., [23,27,30,33,44,45].

In a notable study of the effects of different air fresheners on indoor air quality [46], found that air freshener use resulted in high concentrations (mg/m^3 levels) of solvents and fragrance compounds (e.g., limonene, 12 mg/m^3 after 0.5 h) in the room chamber environment (3 m^3). Emission rates exceeded 2 mg/unit hr for six common solvents (e.g., 35.5 mg/unit hour for ethanol) and for six common fragrance compounds (e.g., 9.1 mg/unit hour for limonene). Thus, in addition to high concentrations of scent substances, air fresheners can emit even higher concentrations of odorless solvents, which may be difficult for people to detect [46].

In the extensive EPHECT project (Emissions, Exposure Patterns and Health Effects of Consumer Products) in the European Union [45], examined air freshener emissions of limonene, alpha-pinene, acrolein, and formaldehyde, and modeled resulting indoor air concentrations. For example, an electric air freshener generated indoor air concentrations of formaldehyde of up to 40 μg/m^3 (30-min rolling average, 24 m^3, 0.1/hour ventilation rate), which represents 40% of the World Health Organisation recommended limit of exposure of 100 μg/m^3 [49].

In a chamber study, a plug-in air freshener emitted d-limonene, dihydromyrcenol, linalool, linalyl acetate, and b-citronellol at 34–180 mg/day over 3 days while air concentrations averaged 30–160 μg/m^3 [35]. In another chamber study with a plug-in air freshener, formaldehyde concentrations reached 28.2 μg/m^3, with total aldehydes approximately 50 μg/m^3 [51].

Emissions by air fresheners used indoors can also migrate outdoors, affect outdoor air quality, and contribute to photochemical smog. For instance, in California in 1997, air fresheners emitted an estimated 7.5 tonnes/day of VOCs, translating to 230 mg/day per person VOC emissions [29].

1.5. How do air freshener emissions affect human health?

Air fresheners can contribute to human exposure to primary and secondary air pollutants [29,45]. Air freshener exposures, even at low levels, have been associated with a range of adverse health effects, which include migraine headaches, asthma attacks, breathing difficulties, respiratory difficulties, mucosal symptoms, dermatitis, infant diarrhea and earache, neurological problems, and ventricular fibrillation (e.g., [6,18,25,27,30,34,38,39,45,50].

Recent population studies have investigated the prevalence and