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Review article

Effects by inhalation of abundant fragrances in indoor air – An overview

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A R T I C L E I N F O

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A B S T R A C T

Odorous compounds (odors) like fragrances may cause adverse health effects. To assess their importance by inhalation, we have reviewed how the four major abundant and common airborne fragrances (α-pinene (APN), limonene (LIM), linalool (LIL), and eugenol (EUG)) impact the perceived indoor air quality as odor annoyance, sensory irritation and sensitization in the airways. Breathing and cardiovascular effects, and work performance, and the impact in the airways of ozone-initiated gas- and particle phase reactions products have also been assessed.

Measured maximum indoor concentrations for APN, LIM and LIL are close to or above their odor thresholds, but far below their thresholds for sensory irritation in the eyes and upper airways; no information could be traced for EUG. Likewise, reported risk values for long-term effects are far above reported indoor concentrations. Human exposure studies with mixtures of APN and LIM and supported by animal inhalation models do not support sensitization of the airways at indoor levels by inhalation that include other selected fragrances. Human exposure studies, in general, indicate that reported lung function effects are likely due to the perception rather than toxic effects of the fragrances. In general, effects on the breathing rate and mood by exposure to the fragrances are inconclusive. The fragrances may increase the high-frequency heart rate variability, but aerosol exposure during cleaning activities may result in a reduction. Distractive effects influencing the work performance by fragrance/odor exposure are consistently reported, but their persistence over time is unknown. Mice inhalation studies indicate that LIM or its reaction mixture may possess anti-inflammatory properties. There is insufficient information that ozone-initiated reactions with APN or LIM at typical indoor levels cause airway effects in humans. Limited experimental information is available on long-term effects of ozone-initiated reaction products of APN and LIM at typical indoor levels.

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1. Introduction

Numerous odorous compounds (odors) are present in indoor air. For shortness, we use “odors” synonymous with “odorous compounds”, which may have a pleasant or unpleasant smell. They are emitted from several construction, consumer and cleaning products, including air fresheners, plants and flowers, food and beverages. For instance, linalool (LIL) from orange blossoms (Arey et al., 1991) and limonene (LIM) from cleaning products, meals, drinks, services, and perfumes (Guan et al., 2014). Also, secondary reactions of construction products produce many odors (Uhde and Salthammer, 2007). Dietary intake from food ingredients is an alternative route of exposure; thus, LIL and LIM are major flavoring compounds in Earl Grey tea resulting in both dietary and inhalative exposure (Orth et al., 2013; Wolkoff, 1990). Several of the most common mono-terpenes with α-pinene (APN) as the major one emitted from pine and spruce construction products (Risholm-Sundman et al., 1998) are also inhaled during forest walking, e.g. from pine wood trees, and accumulated in plasma (Sumitomo et al., 2015).

Odors may cause severe adverse health effects. Thus, diacetyl (butter flavor) has caused life threatening lung disease (bronchiolitis obliterans) (Kreiss et al., 2002); this has, however, only been observed in the general population at unusual and extreme exposures (Eigilman and Schilling, 2012). Odors may also be carcinogenic. For instance, safrole and isosafrole (IARC, 1975) and cinnamyl anthranilate (IARC, 1982) are considered animal carcinogens. Skin application of perfumes may cause contact dermatitis (Hesterberg et al., 2011), which is a major public health problem (Groot and Frosch, 1997).

Potential adverse health effects from exposure to odors is of public concern, especially in view of perceived indoor air quality (IAQ), thus, we evaluate health effects from airborne fragrances in indoor air. Focus, in general, has been the exposure of asthmatics and chemically sensitive people suffering from idiopathic environmental intolerance (multiple chemical sensitivity), but the concern covers the population, at large (Andersson et al., 2016; Dalton and Jaén, 2010). High prevalence (9–16%) of people complaining about odors has been reported worldwide that in part differs by the questionnaire formulation and questionnaire technique, e.g. telephone interview (Berg et al., 2008; Caress and Steinemann, 2009; Hausteiner et al., 2005; Kreutzer et al., 1999); the prevalence, however, should be considered with caution due to responding bias, e.g. (Waserman and Keith, 2009). Furthermore, symptom reporting may be influenced by several personal factors as negative affectivity or being a “worrier”, e.g. Dalton and Jaén (2010). Based on epidemiological studies, both professional and domestic cleaning has shown strong associations with adverse effects in the airways, e.g. asthma or exacerbation thereof (Folletti et al., 2014; Siracusa et al., 2013; Vandenplas et al., 2014b); however, the causative cleaning agents, have not adequately been identified; thus, effects of fragrances in these products are unknown.

Fragrances are ubiquitous in indoor air. They are emitted from numerous consumer and cleaning products, e.g. Steinemann (2015) and Uhde and Schulz (2015); either as constant or temporary sources such as household consumer products (e.g. air fresheners, cleaning agents, insecticides), personal care products (e.g. hairstyle products, perfumes), and scented candles, e.g. Bartsch et al. (2016), Petry et al. (2014), and Trantallidi et al. (2015). The number of fragrances is about 3000 (Groot and Frosch, 1997). Four of the most common volatile organic compounds (VOCs) used in fragrances or mixtures thereof are APN, LIL, and LIM, e.g. ter Burg et al. (2014) and Yazar et al. (2010), and eugenol (EUG) in scented candles (Bartsch et al., 2016).

It is not possible to make generalized statements about all fragrances and their potentially associated health effects caused by inhalation. Thus, the current knowledge has been compiled about inhalative exposure to the four and most common fragrances in indoor air with the purpose to assess their impact on the IAQ and potential airway and cardiovascular effects; also, including their ozone-initiated gas-phase and surface reactions, which may be associated with airway effects (Rohr, 2013). Since there is public concern about the use of fragrances (and associated odor/scent), additional information has been compiled of fragrance/odor perception to achieve a better understanding of their potential influence on perceived IAQ, health, and work performance.

2. Method

The four fragrances, α-pinene, eugenol, limonene, linalool, were searched together with: “airway effects, asthma, distraction, IAQ, health, lung functions, odor, ozone, perception, secondary organic aerosols (SOA), sensory irritation, and performance” in PubMed, Google Scholar, and ECHA (European Chemicals Agency) covering the literature from 2005-July 2016. Additional references were added from our own research collections compiled during the last three decades. Phenomena within environmental idiopathic intolerance of fragrances/odors (MCS) will only be dealt with briefly, where considered relevant.

3. Overview of findings

3.1. Concentration of fragrances in indoor air

Table 1 summarizes reported mean and maximum concentrations of APN, LIL, LIM, and EUG common in consumer products and found in major indoor and outdoor air studies, and in emission studies of consumer products; a few other selected fragrances are included. Reported mean concentrations of APN and LIM are generally below 50 μg/m^3 in homes and public buildings except for specific sources, see Sarigiannis et al. (2011). For instance, a major study in German day care centers ($n = 45$) showed short-term mean concentrations of APN and LIM of 3 and 9 μg/m^3, respectively (Schmidt et al., 2015), while the maximum short-term concentrations in European offices for APN, LIM, and LIL were, 1, 32, and 1 μg/m^3, respectively (Nørgaard et al., 2014a).

Temporary activity-dependent high concentrations may occur, e.g. after spray of an air freshener or use of burning lavender oil; this is in part reflected in the reported maximum concentrations. For instance, the European EPHECT testing program of 16 product categories of selected consumer products for household use modeled maximum micro-environmental concentration in a house over 30 min; simultaneous use

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