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EPHECT III: Health risk assessment of exposure to household consumer products

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HIGHLIGHTS

- Risk associated with inhalation exposure to 15 consumer product classes is assessed.
- Irritative/respiratory effects in relation to 5 indoor air pollutants are studied.
- Health-based limits of exposure for 3 priority pollutants are derived.
- Indoor air pollutant and exposure levels were lower than limits of exposure.
- Considerable contributions to short-term exposures were obtained in some cases.

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ABSTRACT

In the framework of the EU EPHECT project (Emissions, Exposure Patterns and Health Effects of Consumer Products in the EU), irritative and respiratory effects were assessed in relation to acute (30-min) and long-term (24-h) inhalation exposure to key and emerging indoor air pollutants emitted during household use of selected consumer products. A detailed Health Risk Assessment (HRA) was performed for five selected pollutants of respiratory health relevance, namely acrolein, formaldehyde, naphthalene, D-limonene and α-pinene. For each pollutant, the Critical Exposure Limit (CEL) was compared to indoor air concentrations and exposure estimates for the use of 15 selected consumer products by two population groups (housekeepers and retired people) in the four geographical regions of Europe (North, West, South, East), which were derived previously based on microenvironmental modelling. For the present HRA, health-based CELs were derived for certain compounds in case indoor air quality guidelines were not available by the World Health Organization for end-points relevant to the current study. For each pollutant, the highest indoor air concentrations in each microenvironment and exposure estimates across home microenvironments during the day were lower than the corresponding acute and long-term CELs. However, considerable contributions, especially to acute exposures, were obtained in some cases, such as formaldehyde emissions resulting from single product use of a floor cleaning agent (82% CEL), a candle (10% CEL) and an electric air freshener (17% CEL). Regarding multiple product use, the case of 30-min formaldehyde exposure reaching 34% CEL when eight product classes were used across home microenvironments, i.e. all-purpose/kitchen/floor cleaning agents, furniture/floor polish, combustible/electric air fresheners, and perfume, needs to be highlighted. Such estimated values should be evaluated with caution, as these may be attributed to the exposure scenarios specifically constructed for the present study, following a 'most-representative worst-case scenario' approach for exposure and health risk assessment.

1. Introduction

It is widely acknowledged that the built environment is important to public health. According to CDC (CDC, 2011), "the built environment includes all of the physical parts of where we live and work (e.g., homes, buildings, streets, open spaces, and infrastructure)". As we spent a major fraction of our daily time in indoor built environments,

Abbreviations: AF, assessment factor; CEL, critical exposure limit; HK, housekeepers; HRA, health risk assessment; IAQ, indoor air quality; IAQG, indoor air quality guideline; LOAEL, lowest observed adverse effect level; ME, microenvironment; NOAEL, no observed adverse effect level; RET, retired people; (T)VOC, (total)volatile organic compound.

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significant portion of the adverse health effects is attributed to inadequate Indoor Air Quality (IAQ). Diseases caused or aggravated by poor IAQ have been prioritized under the 'European co-ordination action on Indoor Air Quality and Health Effects — ENVIE (2004–2008)', as follows: allergic and asthma symptoms, lung cancer, chronic obstructive pulmonary disease, airborne respiratory infections, cardiovascular disease, odour and irritation (Carrer et al., 2009). Consequently, high level of protection against these effects should be assured (WHO, 1999). The World Health Organization (WHO) has, therefore, established IAQ guidelines for selected pollutants (WHO, 2010) and household fuel combustion (WHO, 2014).

In an indoor environment, consumer products constitute a significant source of air pollutants, along with building materials, indoor combustion sources, ozone and allergens (Jacobs et al., 2007), determining, thus, IAQ in dwellings. In the case of consumer products, e.g., personal care products, cleaning agents and air fresheners, the risk of health effects may increase by inhalation of the emitted volatile organic compounds (VOCs) or semi-VOCs (SVOCs), particulate matter and secondary pollutants formed by ozone-initiated chemistry and degradation (Missia et al., 2012; Kephalopoulos et al., 2007).

Several reviews of epidemiological studies have discussed associations between respiratory effects, i.a. asthma or exacerbation thereof, and sensitizing properties, and exposure to cleaning (Folletti et al., 2014; Quirce and Barranco, 2010; Zock et al., 2010), and personal care products (Bondi, 2011). However, the exact category of cleaning products and their chemicals causing adverse health effects as well as the route of exposure still need to be clarified. Some studies point to products in spray-form to be associated with risk of inhalation and reported health effects (Bédard et al., 2014; Le Moual et al., 2014; Vernez et al., 2006).

Another route associated with respiratory effects has been ozone-initiated reactions with reactive fragrance chemicals (terpenes), common in consumer products (ter Burg et al., 2014), producing a host of gaseous and aerosol phase products (Rohr, 2013). This phenomenon may be further exacerbated by potential stricter energy efficiency measures, such as lower air exchange rate that may lead to elevated concentrations of ozone-reactive VOCs and their oxidation products. Both sensory irritation of upper airways and airflow limitation may be critical effects of concern in common user scenarios involving fragranced consumer products (Nørgaard et al., 2014).

In this context, research is needed to evaluate potential risks associated with inhalation exposure to consumer products, in order to protect and promote health and well-being in the indoor environment. Risks related to emissions from the household use of consumer products can be evaluated according to the procedure of Health Risk Assessment (HRA), the outcome of which can contribute to a future development of risk management guidance and formulation of policy options for risk reduction to be implemented in case of hazardous emissions. In general, in order to obtain an accurate risk assessment in the case of consumer products, product emission rates as well as typical household uses and use patterns of a product are required, as these determine both user's and occupant's exposure, and, thus, the potential health effect. Risks should be assessed both in the case of exposure to the pollutants emitted following single product use and in the case of combined use of consumer products in the course of the day (aggregated exposure to each compound).

The EPHECT (Emission, Exposure Patterns, and Health Effects of Consumer Products in the EU) project (2010–2013) tested emissions from selected consumer products within 15 different product classes, mainly cleaning agents, air fresheners and personal care products (www.ephect.eu). On the basis of a European market study on consumer product uses and user patterns in four EU regions, conducted within EPHECT, the most popular product brands and types, and their profiles for domestic use, were identified (Johnson and Lucica, 2012; Dimitroulopoulou et al., in press-a). Emission testing of these products provided time-derived emission rates for exposure assessment (Stranger et al., 2012, 2013; Bartzis et al., 2015). Consequently, HRA related to five key and emerging indoor air pollutants of respiratory health relevance emitted during household use of selected consumer products was conducted according to a proposed methodology. Specifically, irritative and respiratory health effects were assessed in relation to acute and long-term exposure to acrolein, formaldehyde, naphthalene, D-limonene and α-pinene. In this context, two main outcomes are presented in the present paper; first, the derivation of health-based inhalation Critical Exposure Limits (CELs) for the pollutants under investigation for which WHO indoor air guidelines are not available, i.e. acrolein, D-limonene and α-pinene, and second, the outcome in terms of risk characterization following a comparison of indoor air concentrations in home microenvironments (MEs) and exposure estimates to the five pollutants studied with their corresponding CELs.

The HRA reported in the present study was based on a 'worst-case scenario' and is related to both single and multiple consumer product use. For acute exposure, a 30-min time period was chosen, reflecting exposure during use of the product, whereas for long-term exposure a 24-h time period was selected, reflecting exposure during daily activity of the target population and considered as representative of all days of a year. As target population, the population groups of housekeepers and retired people (>65 years old) were considered, as these spend the majority of their time indoors and are, therefore, mostly exposed to emissions following consumer product use. This paper is based on the results of two interrelated studies in which profiles for domestic use of consumer products in the EU (Dimitroulopoulou et al., in press-a) and population exposure assessment to household consumer products were investigated (Dimitroulopoulou et al., in press-b). Taking into account the underlying assumptions and limitations, this paper reports the outcome of HRA associated with exposure to five priority respiratory health-relevant pollutants, obtained from the use of 15 consumer product classes in households. The present HRA has been carried out simultaneously for eight population groups across Europe, while respecting regional differences in user behaviour, user scenarios, and building ventilation conditions.

2. Methodology

The Health Risk Assessment (HRA) methodology developed to assess the potential adverse effects of respiratory relevance associated with the household use of selected consumer products followed the classical approach comprising four steps: hazard identification, dose–response relationship, exposure assessment, and risk characterization (DG SANCO, 2000). In the first two steps of the HRA procedure, toxicological data concerning the irritative and respiratory effects of short- and long- term inhalation exposure to the selected indoor air pollutants (acrolein, formaldehyde, naphthalene, D-limonene and α-pinene) were evaluated in order to identify the critical effect and the corresponding acute and/or long-term Critical Exposure Limit (CEL) for each compound for subsequent use in risk characterization. Data were retrieved from scientific literature available in databases (e.g. PubMed, Scopus), toxicological reviews of leading health organizations and publicly available risk assessment reports. Health-based CELs were chosen for the purposes of HRA, and more specifically, limit values derived following the application of Assessment Factors (AFs) to the 'No Observed Adverse Effect Level' (NOAEL) or the 'Lowest Observed Adverse Effect Level' (LOAEL) for the critical effect. In the case of compounds for which WHO indoor air guidelines for irritative and respiratory endpoints exist, these values were selected. Otherwise, health-based CELs were derived in the framework of EPHECT (Carrer et al., 2013) and are presented in Section 3.1. AFs considered in this study were related to inter- and intra-species variability, LOAEL-to-NOAEL extrapolation, and time extrapolation (duration of toxicological study).

Regarding the third step of the HRA procedure, exposure estimates to household consumer products were presented in a previous paper (Dimitroulopoulou et al., in press-b); the procedure is briefly