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Technical note

Hierarchical cluster analysis of carbonyl compounds emission profiles from building and furniture materials

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ABSTRACT

Emission profiles of carbonyl compounds from twenty-three indoor materials were assessed by chamber tests and compared by means of a hierarchical cluster analysis. This multivariate method provides a partition into six clusters of materials having statistically similar chemical profiles. Formaldehyde is the most dominant component of emissions mainly related to two types of wood composite products (chipboards and medium-density fibreboards (MDF)) and one finishing plaster. The analysis of clusters reveals that the emission profiles of materials belonging to a same category can have various degrees of variability. Some common pressed-wood products as chipboards and medium-density fibreboards have relatively uniform profiles characterized by its unique emission of formaldehyde. On the contrary, the profiles of Oriented Strand Boards (OSB) and finishing plasters appear very heterogeneous and unspecific in terms of relative dominance between different carbonyl compounds. The finishing plasters are identified as sources of carbonyl compounds (formaldehyde and acetaldehyde, especially). These finishing products have not yet been listed as potential formaldehyde and acetaldehyde emitters. According to these results, the wood composite products can also be ranked in the decreasing order of formaldehyde emission as follows: Chipboards > MDFs > Plywoods > OSBs. In light of these results, more systematic surveillance program on the emissions from materials should be set up by Public Health services to require or request product changes for building and furnishing applications.

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1. Introduction

Among indoor air pollutants, carbonyl compounds are of particular interest due to their abundance in indoor air and to their adverse effects on health [1,2]. In France, a national survey was carried out during the 2003–2005 period by the OQAI (French Indoor Air Quality Observatory) in 554 dwellings designed to be representative of the 24 million French dwellings [3]. It provides a full overview of the state of indoor air quality at the national level and shows that three aldehydes: formaldehyde (median concentration: 19.6 $\mu g\ m^{-3}$), hexanal (median concentration: 13.6 $\mu g\ m^{-3}$) and acetaldehyde (median concentration: 11.6 $\mu g\ m^{-3}$) are among the most abundant identified volatile organic compounds. For these compounds, ratios between indoor and outdoor concentrations largely exceed 1 (10 for formaldehyde, 27 for hexanal and 9 for acetaldehyde) indicating the majority part of the contamination comes from indoor sources. Analysis of the highest indoor levels of formaldehyde found in previous studies [4,5] pointed out more often as sources the wood composite products, especially when these materials are new. Recent field studies combining emission and air concentration on-site measurements confirmed that material emissions are the major contributors to indoor contamination of formaldehyde [6–8].

Moreover, some extensive programs of chamber tests allowed to identify a set of sources of carbonyl compounds among the materials and household products present indoors like the wood-pressed products for formaldehyde, acetaldehyde and hexanal [9], paints for benzaldehyde and hexanal [10] and cleaning products for acetone [11]. However, the diversity of possible sources and addition of their contribution to indoor concentrations make complex identifying the main sources effectively responsible for contamination in a real indoor environment. Analysis of chemical profiles of sources including the emission factors of multiple volatile organic compounds can help to identify the signature of specific sources. Knowledge of these chemical profiles is useful to apply and

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interpret the results of multivariate receptor models like Factor Analysis [12], Positive Matrix Factorization [13] and Chemical Mass Balance [14] which have been used intensively for source apportionment in ambient air. In the field of indoor air, the application of these receptor models is much more limited probably due to lack of specific source profiles clearly identified and discriminant.

Moreover, the associations of VOC exposure to ill health have been controversially discussed [15,16]. However, some studies showed that exposure to certain VOC including formaldehyde at low concentration levels may already have adverse effects on health [17,18].

The compound concentrations as well as the proportion of these compounds compared to the total exposure could influence, in terms of positive or negative trends, the health relevance of the mixture [19]. The proportion of health relevant chemicals in a VOC exposure is a critical parameter to consider for the assessment of indoor environments and indoor sources.

In this paper, we present a detailed statistical analysis of emissions of six carbonyl compounds from a series of building and furniture materials. The aim of the paper is threefold: (1) to identify materials not yet listed as indoor sources of carbonyl compounds; (2) to compare the chemical profiles of emissions between them according to the nature and use of materials; and (3) to look for the specific characteristics of these profiles of emissions.

2. Materials and methods

2.1. Material samples

Twenty-three materials selected were purchased from a DIY store and represent a diverse set of product categories available for sale in France that are commonly found in homes. They were not intended to be a statistically representative sampling of those categories. The selection process provided that when a material was identified as a carbonyl source, additional materials belonging to the same category were also tested. Through this, we try to appreciate the uniformity degree of emission profiles within the classes of source materials. Sample selection includes both wet products: one glue for wallpaper, four furnishing plasters, one silicone and one expanding foam, and dry products: two Oriented strand boards (OSBs), four Medium-density fibreboards (MDFs), two chipboards, two plywoods, one composite board, linoleum, one ceiling tile, one gypsum board and two raw woods (beech and pine).

Dry materials were cut into sample of 10 cm by 15 cm in order to have an exposed area of the material of 0.015 m^2. For testing, only one main face of material (i.e. 0.015 m^2) is exposed, the edges and opposite face of sample are covered with aluminium foil.

Wet materials were placed into a petri dish of 12 cm diameter with a product thickness of 0.5 cm. Thus, the exposed area of wet materials was 0.011 m^2 under test conditions close to that of dry materials. After filling of the petri dish, the sample is dried under airflow at ambient temperature until its weight stabilizes. The drying time takes several days for the finishing plasters especially.

2.2. Emission test chamber method

Each selected material was tested by the emission test chamber standard method to assess emission rates of six carbonyl compounds (formaldehyde, acetaldehyde, acetone, propanal, benzaldehyde and hexanal) that constitute the chemical profile of material. The experimental device set up for these emission tests is presented in Fig. 1. The emission test chamber is consisted of a glass cylinder with a capacity of 35 L (length: 50 cm and diameter: 30 cm) and contains a glass plate separating the lower part devoted to the generation of air movements by means of three axial fans regulated by a potentiometer from the upper part where the material sample is placed on the glass plate. The cylindrical form of the chamber favours the air recirculation giving a thorough mixing of air in the emission chamber. The air opening in the emission test chamber is produced by a compressor and is dried and chemically filtered in an air purifier (AZ 2020 manufactured by Claind). A first air flow is produced directly by the air purifier and a second air flow comes from a humidifier system consisting of a bubbler filled up

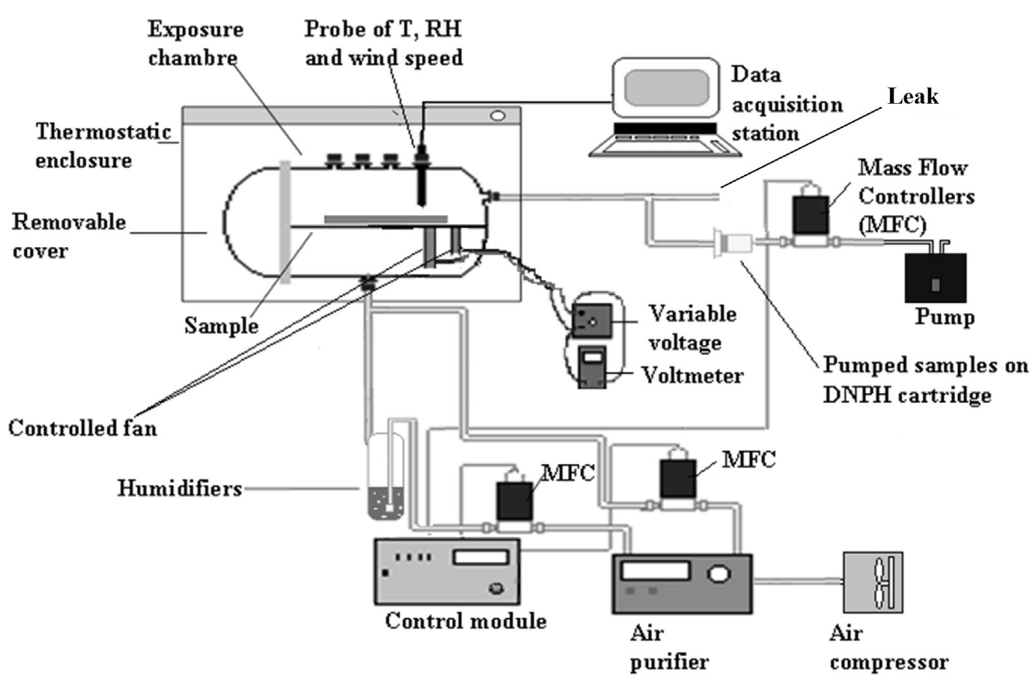

Fig. 1. Emission test chamber device.

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