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# Source apportionment of volatile organic compounds in Hong Kong homes

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ABSTRACT

Indoor volatile organic compound (VOC) data obtained in 100 Hong Kong homes were analyzed to investigate the nature of emission sources and their contributions to indoor concentrations. A principal component analysis (PCA) showed that off-gassing of building materials, household products, painted wood products, room freshener, mothballs and consumer products were the major sources of VOCs in Hong Kong homes. The source apportionments were then evaluated by using an absolute principal component scores (APCS) technique combined with multiple linear regressions. The results indicated that $76.5 \pm 1\%$ (average $\pm$ standard error) of the total VOC emissions in Hong Kong homes attributes to the off-gassing of building materials, followed by the room freshener ($8 \pm 4\%$), household products ($6 \pm 2\%$), mothballs ($5 \pm 3\%$) and painted wood products ($4 \pm 2\%$). Analysis on the source strength in the monitored homes revealed that although six indoor sources were identified and quantified in the Hong Kong homes, only some homes were responsible for the elevated concentrations of target VOCs emitted from these sources. The findings provide us the mechanism of reducing levels of indoor VOCs and ultimately lead to cost effective reduction in population exposures.



## 1. Introduction

Volatile organic compounds (VOCs) are main pollutants in the air [1,2]. In the atmosphere, VOCs react with $NO_x$ in the presence of sunlight to generate photochemical oxidants such as ozone, organic nitrates, peroxides and carbonyls [3]. Hence, it significantly affects the oxidizing capacity and the radiative balance of the atmosphere. On the other hand, many VOCs are proved to be toxic and some, such as formaldehyde and benzene, are carcinogenic [4,5]. In addition, the secondary VOCs, ozone and OH radical generated in the photochemical reaction are often more hazardous to human health and environmental quality [6]. Importantly, since indoor VOC concentrations are generally higher than those outdoors, and people spend most of their time indoors at home, the potential for VOC exposure is the greatest in indoor environment [7–10]. Although simple quantification of VOCs is meaningful, source characterization and apportionment are vital and integrated parts of indoor air evaluation [11]. Identification and apportionment of sources of potentially harmful VOCs in indoor environment provide the only mechanism of lowering levels of these VOCs indoors and ultimately lead to cost effective reduction in population exposures [12].

As such, a number of studies were carried out globally to understand the indoor sources of VOCs in residences. These studies indicated that smoking, cooking, cleaning products, consumer products, renovation products, building materials and carpets were the main VOC sources or activities in homes in Europe, the United States and Asia [12–22]. In most cases, the sources of VOCs at homes were investigated in a qualitative way by using univariate and multivariate analyses [14,18,22,23], mixed linear regression analysis [16,24], variance component analyses [25], random and mixed effect models [26], and the most favorite technique i.e. principal component analysis (PCA) [8,11,12,18,19]. Quantitatively, limited studies were undertaken to determine the source contributions to indoor VOCs at homes [17,27].

Receptor-oriented source apportionment models have often been used to identify sources of air pollutants and to estimate source contributions to air pollutant concentrations. The most widely used models are the chemical mass balance (CMB), principal component analysis (PCA)/absolute principal component scores (APCS), positive matrix factorization (PMF), and graphical ratio analysis for composition estimates (GRACE)/source apportionment by factors with explicit restriction (SAFER), incorporated in the UNMIX model. Among these models, principal component analysis (PCA) is often used as an exploratory tool to identify the major sources of air pollutant emissions and to select statistically independent source tracers [14,28–30], whereas the computation of APCS for each sample is followed by the regression of sample mass concentrations on these APCS to derive each identified source's estimated mass contribution [28]. For instance, Miller et al. [30] successfully apportioned sources of VOCs in indoor environment by applying PCA/APCS model to TEAM (Total Exposure Assessment Methodology) study data.

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