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# Volatile organic compounds in different interior construction stages of an apartment

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ABSTRACT

Building materials are considered as the major sources of volatile organic compounds (VOCs) indoors. During the interior construction process, different building materials are introduced into a room at different times. However, little attention has been paid to the phased material introduction during the interior construction process and the possible implication of this characteristic. In this paper, field measurements were conducted in a new apartment in Beijing from the beginning of interior construction to completion as a case study. A total of five construction stages namely the putty, wall paint, door and doorframe, cupboard, furniture had been measured. Chemical compositions and the concentration variation patterns during the interior construction process were obtained. The VOC concentrations exhibited a pattern of step changes, which suggested the necessity of considering the phased introduction of building materials during interior construction process in indoor VOC modeling. The measured VOC variation patterns could also be used to identify indoor emission sources under certain circumstances.



## 1. Introduction

Volatile organic compounds (VOCs) play an important role in indoor air quality (IAQ) [1]. There are scientific evidences for adverse health effects of several VOCs such as benzene [2,3] and formaldehyde [4,5]. High VOC concentrations have often been observed in newly built or renovated residential buildings [6–9].

The high indoor VOC concentrations are often related to the use of synthetic building materials [10,11]. One of the most effective ways to control VOC concentrations is eliminating main emission sources indoors [12]. Source identification is usually based on the understanding of chemical composition and strength of the emission source [13,14]. Static headspace analysis is a well-known technique to qualitatively character the chemical composition of VOC emissions from building materials [15–17]. Materials are measured separately in an enclosed container. Samples are taken from the inside air of the container and then analyzed by a gas chromatograph/mass spectrometer (GC/MS) to identify the chemical composition [16]. However, headspace analysis could not obtain the emission strength of materials, nor the decay rate. The measurement in dynamic environmental chamber provides emission factors for VOC, and emission profiles as a function of time [18–20]. Thus the source strength and variation characteristic of building materials can be obtained quantitatively. However, the dynamic environmental chamber measurement is quite time consuming and expensive. Moreover, in real world applications, building materials may not be readily available for headspace and environmental chamber measurements.

In reality, the interior construction process of a house or apartment could last for weeks or even months. Different building materials are introduced into rooms at different times. As a result, indoor VOC concentrations during the interior construction process may vary differently as a function of time. And the variation patterns would also have effects on the estimation of short-term and long-term decay. Moreover, the indoor VOC measurements in different building construction stages may be helpful to reveal the on-site chemical composition and decay pattern of building materials. Thus, it is necessary to investigate the concentration behaviors during this period.

However, little attention was paid to the interior construction process either in indoor VOC measurement or modeling. The VOC measurements during the construction stage were also rather rare. Pang et al. [21] measured the VOC concentrations in three households during the construction process. Through indoor VOC concentration data, they found that the living room and kitchen furniture made of particle board and medium density fiberboard emitted the largest

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amount of pollutants. Park et al. [22] conducted field measurements at five construction stages to study the improvement of IAQ by using low emission building materials. They found that the toluene concentration increased dramatically after setting the furniture. This was consistent with the environmental chamber measurement results that the furniture had the worst certification grade. However, these studies mainly focused on the concentration levels at each construction stage. Little attention was paid on the emission characteristics and possible implications of the results.

In this study, we used a new apartment in Beijing, China to investigate the material emission patterns by measuring VOCs at each construction stage. This on-site measurement could help to evaluate the source profiles of different building materials, and shows potential application in emission source identification.

## 2. Materials and methods

### 2.1. A typical interior construction process

An interior construction process could last for weeks or months. Different materials are introduced into the building at different times. Fig. 1 illustrates a typical interior construction process related to VOC emissions. The horizontal coordinate represents various interior construction processes. The vertical arrows represent material introductions. In this paper, we treat a new material introduction as a new construction stage. Specific construction processes may differ in the time schedule and material selection according to people's preferences. While they can be simplified to one stage if all the materials are introduced simultaneously.

Putty is usually applied on the wall as a leveling course. It is widely used in Chinese apartments. After the putty becomes dry, the wall paint is applied on the putty surface. The ceramic tile floor presented in Fig. 1 is not treated as a VOC emission stage because it has little or no VOC emissions [12,23]. Other materials, which may differ case by case, should be considered if previous studies have suggested they could emit VOCs.

### 2.2. Measurement procedures

To get the on-site VOC types and their concentration variation patterns during the interior construction process, measurements are recommended to be conducted after the completion of each construction stage with external windows and doors closed for about 12 h. Thus the apartment can be treated as an enclosed space with small infiltration rate. The doors of the furniture or cabinets are left open to maximize the emissions of VOCs. Internal doors connecting each room are kept open to ensure good mixing inside. Air samples are taken at the center of the room. Chemical composition of each air sample is analyzed by a GC/MS. Concentration variation patterns during the construction process can be obtained by this method. By comparing the concentration values before and after each stage, the emission source strength and decay pattern of the building materials can be evaluated.

### 2.3. Case study

#### 2.3.1. The apartment

Fig. 2 presents the layout of the apartment located in a multi-family apartment building in Beijing, China. The total area of the apartment is 68.5 $m^2$, and the room height is 2.55 m. The occupants hired a professional construction team to perform the interior construction work. Interior construction began on May 15, 2010 and finished on June 6, 2010. A total of six construction stages namely the putty, wall paint, door and doorframe, cupboard (bathroom cabinet included), floor and furniture had been measured. The duration of each construction stage is shown in Table 1. It is a small apartment, most of the construction stages only lasted one day. Wall paint, which was applied twice, took two days. Also showed in Table 1 are the main building materials used in each construction stage. All of the building materials are commonly used in China.

#### 2.3.2. Sampling and analysis of VOCs

After each construction stage was completed, the indoor VOC concentrations were measured at different times which are given in the last column of Table 1. External windows were opened during the interior construction but closed for 12 h before the VOC samples were taken. As the materials used in the putty and wall paint stages belong to “wet” materials, to benefit the drying process, the occupants opened the windows for about 12 h right after the construction completion. Then they closed external windows and doors for another 12 h before VOC samples were taken. For the door


**Fig. 1.** A typical interior construction process in China related to VOC emissions.