Measurements of VOCs emission rate from building materials during bake-out with passive sampling methods

Dong-Hwa Kang¹, Eun-Young Park, Dong-Hee Choi¹, Min-Ki Sung², Seung-Min Lee², Sueng-Jae Lee², You-Sun Min², Myoung-Souk Yeo³ and Kwang-Woo Kim³

¹Department of Architecture, Graduate School of Seoul National University, Korea
²Institute of Construction Technology, Samsung Engineering & Construction, Korea
³Department of Architecture, Seoul National University, Korea

Corresponding email: snukkw@snu.ac.kr

SUMMARY

Bake-out of buildings is believed to have a potential to reduce indoor air pollution caused by VOCs and formaldehyde emitted from building materials although controversial discussions have been suggested. To clarify the effectiveness of bake-out, in this study, the variation of VOCs and formaldehyde emission rate from building material were investigated in residential housing units with passive sampling methods. For about a month, measurements of emission rate are carried out on various building materials such as wood based materials and paper based materials installed in real buildings at which bake-out was conducted. According to the results, the toluene emission rate from wood based materials clearly decreased with only ventilated conditions during bake-out. However, the toluene emission rate from wall paper decreased regardless to the ventilation condition. Compared to toluene emission rate, we couldn’t observe a clear reduction of formaldehyde emission rate from most of building materials.

INTRODUCTION

Recently, due to synthetic building materials used in buildings, IAQ problem has become a major public concern in newly constructed apartment buildings. For resolving this problem, Indoor Air Quality Management Act[1], a regulation concerning the concentration limitations of formaldehyde and 5 VOCs in new apartment buildings, was enforced by the Ministry of Environment of Korea and came into effect from May 30, 2004. According to this act, construction companies, which construct apartment complexes, are required to measure the concentration levels of 6 toxic substances and give a public notification before the residents move in. To meet the requirements of the government regulations, source control strategies such as using low-emission building materials are widely used. However, Indoor concentration level of chemical compounds is partly high especially at pre-occupancy stage, due to high outdoor temperature in summer. With these backgrounds, construction companies are considering building bake-out as the urgent method which can be applied after the construction complete.

Based on the result of the former researches on building bake-out [2],[3], it is believed that building bake-out has the potentials to improve indoor air quality in residential buildings, although contradictory results have been also reported [4],[5]. To clarify the effectiveness of bake-out, it is required to investigate variation of pollutants emission rate from building materials installed in buildings due to bake-out procedures.

The objective of this study is to investigate emission rate variations of VOCs emitted from building materials commonly used in residential housing units during building bake-out.
Using passive sampling methods, measurements of variation of VOCs emission rates from various building materials such as flooring materials, wall papers, and furniture were conducted during bake-out.

**RESEARCH METHOD**

**Description of test house**

Measurements were taken on residential housing units to evaluate variations of VOCs and formaldehyde emission rates due to building bake-out. Two identical residential housing units with an area of 85m², finished and furnished with the same materials were selected from the apartment buildings located in Seoul, Korea. A radiant floor heating system was adopted in test housing units. Mechanical ventilation system throughout the residential unit was not used, but rather an exhaust fan was installed in the kitchen and bathrooms. As shown in the unit floor plan shown in Figure.1, all of the room can be ventilated by natural means of opening windows and doors. In the units, the wall paper with water glue was finished on walls and ceilings. On the floors, a wood based material which is laminate flooring was finished. A different types of furniture was installed in bedroom2 and kitchen.

![Figure 1. Floor plan of the unit &Measuring Point](image)

**Table 1. Investigated materials**

<table>
<thead>
<tr>
<th>Measuring point</th>
<th>Measured Location</th>
<th>Material composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>indoor air</td>
<td>-</td>
</tr>
<tr>
<td>P2</td>
<td>Ceiling in living room</td>
<td>water glue + wall paper</td>
</tr>
<tr>
<td>P3</td>
<td>Wall in living room</td>
<td>water glue + wall paper</td>
</tr>
<tr>
<td>P4</td>
<td>Floor in living room</td>
<td>wood based material</td>
</tr>
<tr>
<td>P5</td>
<td>furniture in bedroom</td>
<td>wood based material</td>
</tr>
<tr>
<td>P6</td>
<td>furniture in kitchen</td>
<td>wood based material</td>
</tr>
</tbody>
</table>

**Measurement Schedule**

Measurements of VOCs emission rates from various building materials were taken three times in nearly same temperature and ventilation conditions. As shown in Figure 1 and Table 1, measurements were taken at ceiling, wall, floor and two types of furniture. Indoor concentration was also measured. During all of the measurements, the test units were shut tightly and the air temperature of the units was maintained around 30°C. After the initial measurement was carried out, the test units started to operate the heating system to raise the indoor temperature to reach 35°C with different ventilation rates for five days. Then, all the units were naturally ventilated by opening windows for two days, and baked out for another five days. The second measurements were carried out after the test units were ventilated by opening windows for two days to be sufficiently cooled down. Measurement schedules and points are shown in Figure 2 and Table 1, respectively.
Measurement and analysis methods
For measuring emission rates of building materials installed in test units, passive sampling methods were used [6]. VOC-SD and DSD-DNPH passive samplers were used for sampling VOCs and formaldehydes respectively. Each sampler was inserted into an instrument made of stainless steel and the sampling was carried out for 24hous. VOC-SD samplers are analyzed by GC/MS after solvent desorption using CS2 and DSD-DNPH samplers are extracted with acetonitrile and analyzed by HPLC. Among the various pollutants, toluene and formaldehyde levels were presented in this paper, and relative humidity and indoor temperature in the units were also measured.

RESULTS AND DISCUSSION

Environmental conditions
The room temperature of each unit for whole test periods was plotted in Figure 4. The room temperature was maintained at around 30°C before the bake-out. During the bake-out, the
Room temperature of both units reaches 35°C. Although, unit 2 was ventilated by operating fans and opening the windows, indoor temperature sufficiently reached about 35°C due to fairly high outdoor temperature around 30°C in summer. The figures show both of the units were under very similar temperature conditions in spite of the different ventilation condition.

![Graph A](image1.png)  ![Graph B](image2.png)

**Figure 4.** Indoor air temperature a) Unit 1, b) Unit 2

**Variation of pollutants emission rates**

Toluene emission rates of the tested materials and indoor concentration in units 1 and 2 are plotted in Figure 5. Regardless to the ventilation conditions during bake-out, after bake-out, the emission rate of toluene from all kinds of materials is clearly reduced compared to the initial values at measurement T2. At measurement T3, however, emission rate at T2 fairly rose up compared to the values at measurement T2, but most of them still has lower values than the initial values. These rises of the emission rate were observed in all kinds of materials. Although it is hard to interpret this result, one possible explanation is that rearrangement of pollutants distribution inside materials increases their emission rate. Based on the comparison of the values measured at the final measurement with the initial values, the emission pattern of wood based materials appears to be different from wall paper. Clear decrease of toluene emission rate from wood based materials such as floorings and furniture is observed, while the toluene emission rate in unit 1 slightly decreased or even rose up compared to the initial values. It is seemed that toluene emission from wood based materials is affected by ventilation conditions.

Formaldehyde emission rates of the materials and indoor concentration are plotted in Figure 6. The emission rate of formaldehyde showed the different patterns with that of toluene. In contrary to the result of toluene, we didn’t observe reduction of formaldehyde emission rate after bake-out. In unit 1, which was shut tightly during bake-out, formaldehyde emission rate rose or maintain at approximately same level compared to the initial level.

Based on the result, it is found that the variation of pollutants emission rates depends on types of materials and pollutants as well as ventilation rates. If materials showing a good reduction of pollutants emission rates by bake-out were mostly installed in a building, we could expect a better IAQ after conducting bake-out procedure. The effectiveness of conducting bake-out will vary with emission characteristics and installed area of each building material. Consequently, investigation of emission characteristics of building materials are required prior to conduct the building bake-out for confirming in the result of better IAQ by bake-out.
Figure 5. Emission rates of toluene a) indoor air(P1), b) ceiling in living room(P2), c) wall in living room(P3), d) floor in living room(P4), e) furniture in bedroom(P5), f) furniture in kitchen(P6)

Figure 6. Emission rates of formaldehyde a) indoor air(P1), b) ceiling in living room(P2), c) wall in living room(P3), d) floor in living room(P4), e) furniture in bedroom(P5), f) furniture in kitchen(P6)
CONCLUSION

In this study, we measured VOCs and formaldehyde emission rate from building materials during bake-out to clarify the effectiveness of bake-out conduction. Measurements of emission rates were carried out with passive sampling method for about one month in residential housing units.

The result shows bake-out easily drops down toluene emission rate compared to formaldehyde emission rate. In unit 1, which was shut tightly during bake-out, toluene emission rate from wall paper prominently decreased. In unit 2, which was ventilated during bake-out, toluene emission rate from wood base materials has relatively large reduction rate. However, formaldehyde emission rate is not affected by bake-out. Based on the result, we concluded that the effectiveness of conducting bake-out will vary with emission characteristics and installed area of each building material. Because indoor air quality can be better or worse according to the emission characteristics and installed area of building materials, investigation of emission characteristics of building materials are required prior to conduct the building bake-out for confirming in the result of better IAQ by bake-out.

REFERENCES