The effects of controlling strategies on chemical air pollution in the office.

Asako Hasegawa[a], Eriko Takehiro[b*], Takeshi Wakui [b*]

[a] Kumamoto University, Kumamoto, Japan

[b] Kajima Technical Research Institute, Tokyo, Japan

*corresponding author: asako@gpo.kumamoto-u.ac.jp

(Received 30 November 2009; accepted 7 December 2009)

This study aimed to eliminate chemical air pollution and its influence on occupants' health in office buildings. In this paper, two strategies were adopted to reduce volatile organic compounds (VOCs) and their removal effects were investigated in actual office rooms. Firstly, a chemical filter was installed in ceiling mounted indoor units of packaged air conditioners in 2 office rooms and VOCs concentration in the rooms was measured before and after operation. The result shows that VOCs concentration can be reduced to about 20% by this filter. On the other hand, forced ventilation with hot-humid outdoor air during summer was applied to the office room as "natural bake-out" strategy in Kumamoto. Three aldehydes and four VOCs were measured intermittently to compare to their natural decay and the concentration of chemical substances after the bake-out could be decreased 6 months ealier than the case without this strategy. It was proved that both strategies have a significant effect on reducing VOCs.

Key words: Indoor Air Quality (IAQ), Volatile Organic Compounds (VOCs), Chemical filter, Bake-out, Office

1. INTRODUCTION

In Japan, the Ministry of Land, Infrastructure and Transport amended the Building Standard Law in 2003 to control indoor chemical pollution, mainly caused by formaldehyde (HCHO) [1]. Architectural materials that emit a significant amount of HCHO must not be used, and the air exchange rate must exceed 0.5 h^{-1} consistently with a mechanical ventilation system. This amendment seems to have had a positive effect and health complaints due to exposure to high concentrations of HCHO in new buildings have reduced. However, there is a possibility that health effects can be caused by other VOCs in new buildings and/or by long-term exposure to low concentrations of such chemicals.

The purpose of this study was to validate strategies to remove VOCs from claimed rooms in a university building after renovation work. Two types of strategies implemented in renovated rooms were validated in order to resolve complaints made by occupants about unpleasant odors caused by VOCs.

2. METHOD

A renovation work at a certain university in Japan was carried out for 2 years. After the renovation work was completed, the occupants resettled into their respective renovated rooms. Several kinds of chemical substances were emitted from materials, and there were complaints of characteristic odors in the renovated rooms by some occupants. "Natural" bake-out method and a chemical filter were used in the renovated offices of the teachers to solve this problem.

In Kumamoto, outdoor temperature and relative humidity in summer are very high. The hot-humid climate in this region is considered to be suitable for forced ventilation systems to discharge indoor chemicals, as in the "bake-out" method. To validate the effects of forced ventilation with hot-humid outdoor air, the concentrations of HCHO, acetaldehyde, acetone and major VOCs in the room were measured before and after the implementation of this strategy.

On the other hand, a major Japanese construction company and a filter manufacturer have developed an activated-carbon-based filter for indoor air conditioning units to remove indoor chemical pollutants [2]. The performance of this filter was examined in two rooms for teachers by measuring the concentrations of aldehydes and VOCs before and after using the filter.

The concentrations of HCHO, acetaldehyde and acetone were measured by HPLC, as in ISO 16000-3 [3]. The VOCs were collected in a tube filled with Tenax TA and the concentration

was quantified by gas chromatography/mass spectrometry with a thermal desorption system following ISO/DIS 16000-6 [4].

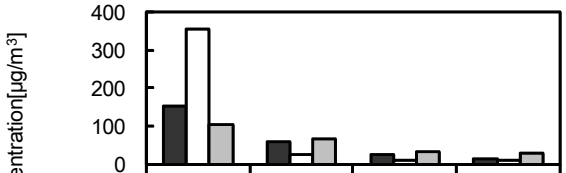
The three rooms had a floor area of 22 m^2 and an air volume of about 60 m^3. A mechanical ventilation system and an air conditioner were installed in the ceiling.

3. RESULTS AND DISCUSSION

In a teacher's renovated room, HCHO, acetaldehyde, acetone and 4 targeted VOCs were measured in the summer after the first renovation phase. The result showed that the initial concentrations of formaldehyde and toluene exceeded the guideline values recommended by the Ministry of Health, Labour and Welfare. To reduce chemical pollution, forced ventilation using hot-humid outdoor air was applied in this room for 2 weeks. In this method, the windows of the room were kept open and a mechanical ventilation system was installed and operated at its maximum capacity. The door, which is located at the opposite side of the window in the room and connected to the corridor, was closed for security. This could achieve an air exchange rate of 0.6 h^{-1} at the minimum under the calm weather. This ventilation was carried out every day during the summer vacation and during working hours on weekdays, for a total of 195 hours. The average temperature and relative humidity in the room were 30°C and 70%, respectively.

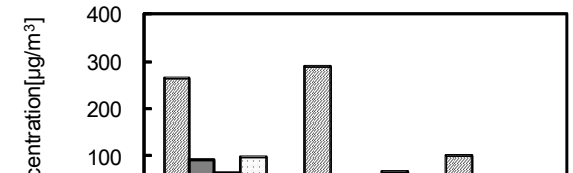
The results of this strategy are shown in Figures 1 and 2. The VOC data was insufficient to create a decay curve. Thus, the decay curve of acetaldehyde was used to compare the reduction in chemical pollution achieved by forced ventilation and natural ventilation at an air exchange rate of 0.3 h^{-1}. It was shown that forced ventilation might reduce chemical pollution around 6 months earlier than using just natural ventilation. This strategy does not require electric power, does not use any combustion appliances, and there is no possibility of generating other compounds through chemical reactions. It might be an ecological strategy to remove indoor chemicals in situations similar to the one described here.

In two new rooms, activated carbon filters were installed in each indoor air conditioning unit to remove VOCs. Table 1 shows the results of field measuring and removal efficiency of the filter. It was proved that VOCs were reduced to approximately 20% of their initial concentration by the filter. Thus the use of the filter proved to be an effective strategy to control chemical pollution in accordance with our expectations.



	initial	after vent	2 months later	6 months later
Formaldehyde	152.9	57.9	24.8	14.3
Acetaldehyde	355.3	26.5	12.4	11.8
Acetone	102.9	67.5	33.2	28.5

Figure 1 Aldehyde concentrations in the room.



	initial	after vent	2 months later
Toluene	266.0	290.5	102.2
Xylene	93.5	56.5	25.8
Stylene	64.0	34.5	8.7
Ethylbenzene	99.0	69.0	35.1

Figure 2 VOC concentrations in the room.

4. CONCLUSIONS

Forced ventilation using hot-humid air and the use of the activated carbon filter in air conditioners could contribute to reducing the concentration of indoor VOCs.

Recently, formaldehyde and toluene have been targeted for elimination by many material manufacturers in Japan. The amendments of the Building Standard Law urge continuous ventilation to reduce indoor chemical pollution; however, occupants are allowed to stop operating the ventilation system in an effort to conserve energy. It is necessary to develop an energy-efficient ventilation strategy to ensure the well-being of the occupants.

Table 1 Removal effects of the chemical filter

	conditions	initial concentration [μg/m^3]	conditions	filtered concentration [μg/m^3]	removal rate [%]
room-1	16.4 °C 53 %RH	TVOC[a)]: 1638 SVOC[b)]: 87 TOC[c)]: 1725	15.4 °C 52 %RH	TVOC: 227 SVOC: 17 TOC: 244	86 80 86
room-2	19.8 °C 38 %RH	TVOC: 948 SVOC: 68 TOC: 1021	19.1 °C 38 %RH	TVOC: 138 SVOC: 20 TOC: 161	85 71 84

a) TVOC: Total Volatile Organic Compounds (C6-C16)

b) SVOC: Semi-Volatile Organic Compounds (>C16)

c) TOC: Total Organic Compounds (boiling point: 0-400°C)

REFERENCES

[1] The Ministry of Land, Infrastructure and Transport in Japan, The amendments of Building Standard Law, 2003.

[2] T. Wakui et al., Development of VOC removable filter for ceiling cassette type air conditioner, 24th Annual Tech. Meeting on Air Cleaning and Contamination Control, 2006, 267-269

[3] International Organization for Standardization, ISO 16000-3 Indoor air - Part 3: Determination of formaldehyde and other carbonyl compounds - Active sampling method, 2001.

[4] International Organization for Standardization, ISO/DIS 16000-6 Indoor air - Part 6: Determination of volatile organic compounds in indoor and chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography MSD/FID, 2004.