Indoor particle concentration related to occupant behavior of Korean residential buildings

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ABSTRACT

In recent years, PM, which is one of the most important indoor air pollutants, has attracted a great deal of attention. PM is mainly generated by occupant activities. In particular, cooking and smoking are occupant activities that have the greatest effect on the indoor PM concentrations. The objective of this study is to analyse indoior PM concentration and occupant behavior of Korean residential buildings. PM concentration increased rapidly in a short time during the cooking process. In addition, it was confirmed that the cooking-generated PM diffuse rapidly and contributed to increasing the PM concentration in the living room. In the cooking process, the range-hood was operated most of the time, but the PM diffused into the living room. Therefore, there is a need for additional ventilation method to prevent diffusion of cooking-generated PM.

KEYWORDS

Indoor particle; Occupant behavior; Cooking; Residential building

1 INTRODUCTION

Indoor PM generation is caused by an inflow of outside air or occupants' activities. It appears in various sizes, shapes and chemical compositions depending on the type of source.(Wilson & Suh, 1997) Typical occupants' activities that affects the PM concentrations include cleaning, smoking and cooking. In the cooking process, PM occurs due to heat generated by combustion in a complex manner. Most of the PM generated during cooking has a particle size of 1μm or less.(Afshari, Matson, & Ekberg, 2005) In particular, cooking-generated PM constitute the largest portion of the indoor PM generation when the PM concentration of the outside air is not high.(He, Morawska, Hitchins, & Gilbert, 2004) Therefore, measures against cooking-generated PM are needed to decrease indoor PM concentration.

Ventilation is necessary to remove the cooking-generated PM. Mechanical ventilation and natural ventilation are the main ventilation methods for apartment houses. According to Tian et al., mechanical ventilation is more effective than natural ventilation at removing the cooking-generated PM.(Tian et al. 2008) In South Korea, most apartment houses are equipped with ventilation devices.

This study analyzes factors affecting indoor PM. The PM concentrations were measured for 24 hours in 8 housing units of the Korean residential building. In addition, the types of cooking and occupant behavior were investigated through a questionnaire survey.

2 OVERVIEW OF FIELD MEASUREMENT

In this study, indoor PM concentration in domestic residential buildings is analyzed through field measurement. And occupant activities were figured out through questionnaire survey.

2.1 Field measurement

The field measurement was conducted on 8 housing units of an apartment house located in a downtown area. The PM concentration was measured based on the particle number concentrations. The indoor PM concentrations in 10 households were measured for 24 hours (in 30 second intervals) daily in December 2017, and the changes in concentrations for one day were analyzed.

Table 1. Contents of field measurement

Category	Item	Contents
Target building	Building type	Domestic residential buildings(Apartment house, 8units)
	Measurement points	Outdoor, Living room, Kitchen
	Measuring material	Particulate matter
Duration of measurement	Schedule	Dec, 2017
	Measurement period	24 hours(Interval : 30 sec)
Measuring instruments	TSI OPS-3330(4EA)	6 Channel (0.3~0.5, 0.5~0.7, 0.7~1.0, 1.0~2.5, 2.5~5, 5~10 ㎛)
Questionnaire survey	Occupant activity	Cooking, Ventilation, Cleaning, Smoking

Table 2. General information of target buildings

Building no.	Floor areas, m^2	Floor Height, #	No. of occupants	Type of fuels	Type of Ventilation[1)]	Type of Cooking[2)]
1	64	5/5	2	LNG	H+N.V	B,S
2	164	21/25	3	LNG	H+N.V, H	S
3	77.68	3/20	4	LNG	H+N.V, H	B,S
4	51	10/15	2	LNG	H+N.V	S
5	130	13/15	3	LNG	H+N.V	F,S
6	122.7	13/15	2	LNG	H+N.V	B,F,S
7	130	12/15	2	LNG	H+N.V	B
8	138.84	7/15	4	LNG	H	B,F,S

1) Type of ventilation - H: Hood, H+N.V: Hood + Natural ventilation, N.V: Natural ventilation
2) Type of cooking - B: Broiling, F: Frying, S: Soup

(a) Position of measuring instruments

(b) Survey sheet

Figure 2-1. Pictures of field measurement and occupant survey

2.2 Questionnaire survey

occupants' activities were investigated to determine the effects of occupants' activities on the PM concentrations. The operation and time of occupants' activities– such as cooking, ventilation, cleaning and smoking – were collected through questionnaires. With respect to cooking, the start and end time of cooking, the type of cooking and the operation of the range-hood during cooking were investigated in the answering of the questionnaires.

3 RESULTS

The survey results of occupant behavior are summarized in <Table 3>. For ventilation, eight housing units except for one household performed natural ventilation through windows for 23 minutes on average. In Korea, the air temperature and relative humidity are low, and the concentration of PM is high during the winter time. Since the measurements were conducted in December, the ventilation time was not long in comparison. Cleaning was done once for 24 hours in six housing units. The time required for cleaning was 15 to 30 minutes.

All housing units performed cooking more than two times. Most of them operated the range hood during cooking, and turned it off after cooking. No housing unit operated the range hood after cooking. The types of cooking were divided as follows: broiling (15 times), frying (10 times) and soup (16 times). The airflow rate of the range hood was measured at 81-308CMH. In most of the housing units, the range hood was operated at a low airflow rate due to noise.

Table 3. Surveyed data about occupants' activities

No.	Ventilation		Cleaning		Cooking		Airflow rate of rangehood (CMH)
	n	t	n	t	n	Cooking type	
1	-	-	-	-	**Bf/D**	S/B	285
2	2	30/60	-	-	Bf/L/**D**	F/S/S	81
3	4	25/20/12/14	1	20	Bf/**L**/**D**	F,S/B/B,S	119
4	3	5/25/15	-	-	**Bf/L/D**	S/S/B,S	245
5	2	20/20	1	15	**Bf/L/D**	S/ B,F,S/B	95
6	4	25/60/5/20	1	15	**Bf/L/D**	F,S/ B,F,S/B	95
7	2	30/5	1	15	**Bf/L/D**	B/B/B,F	125
8	1	25	-	-	Bf/**D**	B,S/B,F,S	308

Notes

n : Number of times

t : Time(run-time)

Bf/L/D : Breakfast/Lunch/Dinner (Bold text : Range-hood operated)

Type of cooking - B: Broiling, F: Frying, S: Soup

Figure 3-1 (a)-(d) show the indoor and outdoor PM concentrations and occupants' activities for each house. The blue line indicates the living room, the orange line the kitchen, and the black dotted line the outdoor PM concentration. The red dotted box in the graph indicates the cooking activity, and the grey dotted box indicates the ventilation or the cleaning activity.

In general, the outdoor PM concentrations are very high in houses next to a large road(house 2, 5,6,10). In addition, houses located in Seoul and Gyeonggi show higher outdoor PM concentrations than those located in Daejeon. In these houses, the indoor PM concentrations show a tendency to rise to some extent during ventilation. Therefore, a great deal of care is

required to apply natural ventilation in a house adjacent to a large road or in a house located in the downtown area of a large city.

The occupant activities that affect the indoor PM concentrations include cooking, ventilation, cleaning and smoking. The ten housing units are all non-smoking households. Among the rest of occupant activities except for smoking, cooking was found to have the greatest effect on the indoor PM concentration. It was also found that the indoor PM concentration increased rapidly in a short time during the cooking process. In addition, it was confirmed that the cooking-generated PM disperse rapidly and contributed to increasing the PM concentration in the living room. In the cooking process, the range-hood was operated most of the time, but the PM dispersed into the living room. Therefore, it was demonstrated that it is difficult to prevent the dispersion of the cooking-generated PM only through the operation of the range-hood. In addition, the range-hood was turned off after the completion of cooking in the entire cooking process, which resulted in a slow discharge of PM dispersed in the room.

The factors that have the greatest influence on the emission of cooking-generated PM are cooking types and materials. Figure 3-2 shows the indoor PM concentration according to the type of cooking. The data was obtained by extracting the PM concentration data for one hour after the start of cooking. The results confirmed that among the three types of cooking (broiling, frying, soup), the highest PM concentration was found when the broiling type was used for cooking. Even though broiling contributes to high PM emissions, it is the most common cooking method among Koreans. Therefore, there is a need for countermeasures against PM generated by broiling.

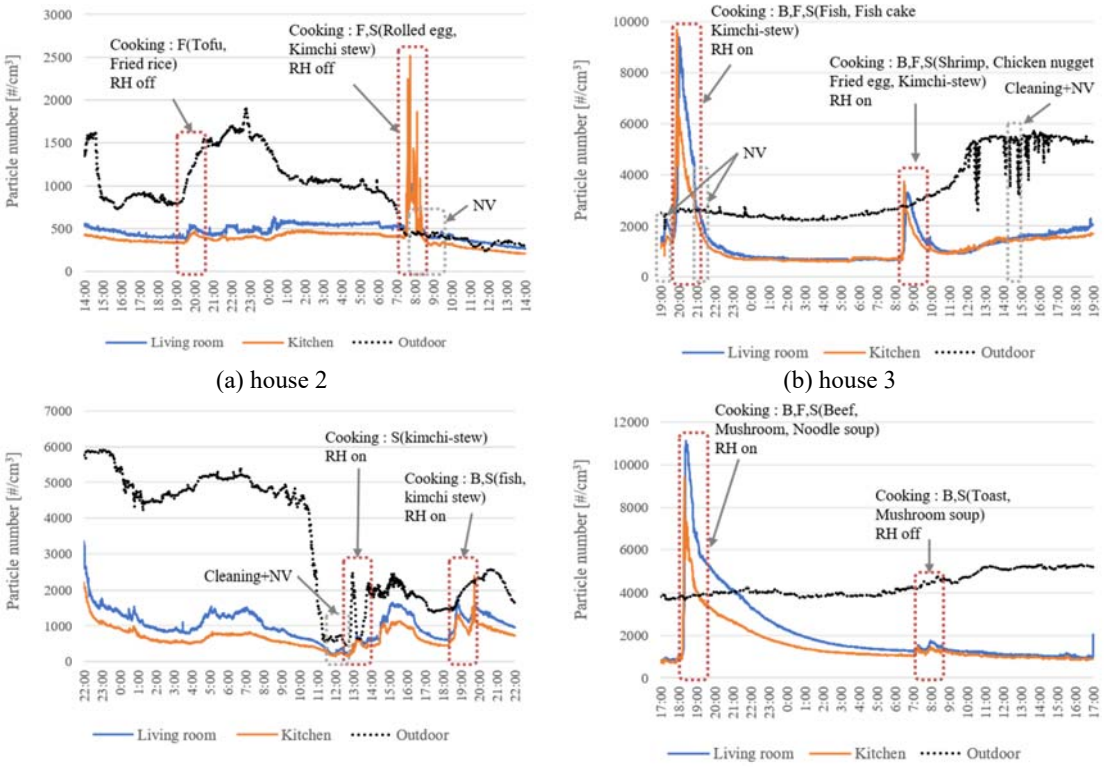

Figure 3-1. Indoor and outdoor PM profile and occupant activities

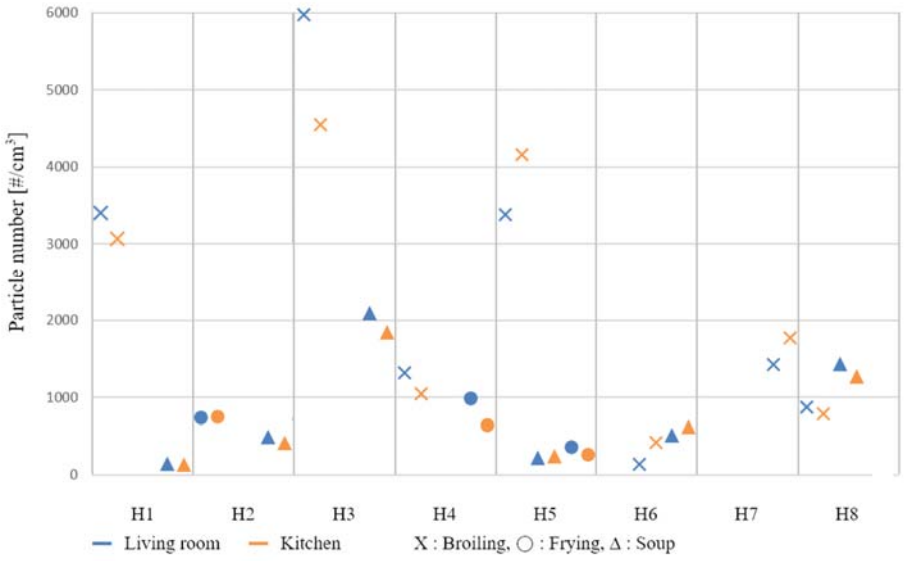

Figure 3-2. PM concentration by each type of cooking

4 CONCLUSIONS

In this study, the PM concentrations were measured for 24 hours in eight housing units of Korean domestic residential building. As a result of the measurements, several problems were found in the indoor PM concentrations in domestic residential buildings. The problems derived in this chapter are as follows.

1) Difficulty of natural ventilation
- The outdoor PM concentrations are high in most of the housing units.
- The indoor PM concentrations increase when natural ventilation is done through open windows.

2) Emission of cooking-generated PM
- A large amount of PM is emitted in a short time during cooking.
- The emitted PM rapidly disperses to adjacent spaces.
- The dispersed PM is not directly discharged and remains in the room for a considerable time.
- The emission of cooking-generated PM is very high when food is cooked according to the broiling method, which is widely used in Korea.

5 ACKNOWLEDGEMENTS

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