Ventilation systems to minimize food odor spreading in high rise residential buildings

T. Kim, B. Park
Yonsei University, Korea

S. M. Lee, J. H. Lee
Samsung Construction & Engineering, Korea

Y. Lee
Korea Institute of Construction Technology, Korea

ABSTRACT

A food odor spread is one of the air quality problems in high rise residential buildings in Korea. The food odor is mainly produced during the cooking of food. The food odor is generated in the limited spaces like in the kitchen and at a table. The ventilation systems in the buildings designed to control air quality actually make the food odor spread more widely. To control the food odor spread, another types of ventilation systems are needed. In the paper, the kitchen ventilation system to prevent the food odor spread is introduced. To evaluate the performance of the systems, field measurements were conducted using the tracer gas method in high rise residential buildings. It was found that the systems had good performance to reduce the spread of food odor.

1. INROUCTION

Recently, many high-rise residential buildings that maximize land use and offer high quality and convenience for the residences, are being constructed in Korea. High-rise residential buildings have numerous merits. However, they do have problems in environmental aspects, such as the lack of ventilation, condensation problems, the reverse flow of kitchen exhaust, stack effect due to the differences of pressure of each floor, and a deterioration of indoor air quality due to the lack of ventilation. The kitchen is the space that produces most of the pollutants in the residential area and of these, food odor produced during the cooking and eating causes much displeasure to the residents. Food odor does not cause harm directly to one's health, compared to the chemical substances generally produced from construction materials such as volatile organic compounds (VOCs) or formaldehyde (HCHO) However, it can produce discomfort to those inside, even at a low concentration, and has the characteristic of developing in specific places, at certain times. Therefore, there is a limit to preventing the spread of odor with the extant ventilation facilities, and a different ventilation method is necessary for the indoor pollutants. In this research, a strong exhaust ventilation system, which can improve the exhaust system in kitchens and exhaust the odor in a short period of time, was proposed to prevent the spread of the food odor that develops when cooking. The proposed system has been installed in a high-rise residential building that is actually being constructed, and the odor exhausting capacity was measured by using the Tracer Gas method.

2. CONCENTRATION AND INTENSITY OF ODOR

There are largely two kinds of smell: fragrance or scent refers to the one that makes people feel pleasant and odor which refers to the one that makes people feel unpleasant. Generally, to determine foul odor, there are four known characteristics, which are:

•odor intensity (the dimensions of senses that humans can feel),

Table 1:.Intensity of odor

Chemistry compo-nent	Odor element*[1]				Smell	Scale (unit: ppm)*[2]				
	Live-stock	Fish	Kim-chi*[3]	Starch		1	2	3	4	5
Hydrogen sulfide (H2S)	2	1	2	1	Rotten egg	0.0005	0.0056	0.063	0.72	8.1
Methyl mer-chaptan (CH3SH)	3	3	3	3	Onion	0.0001	0.00065	0.0041	0.026	0.16
Tri-methyl amine ($(CH_3)_3N$)	-	1	2	-	Fishy	0.00011	0.0014	0.019	0.24	3.0

*1: the cause of offensive odour, 2: The material which is detection , 3: The material which is detection possibility
*2 Scale : 0 None, 1 Threshold, 2 Moderate, 3 Strong, 4 Very Strong, 5 Over Strong
*3 Korean traditional food. It has stinky odor.

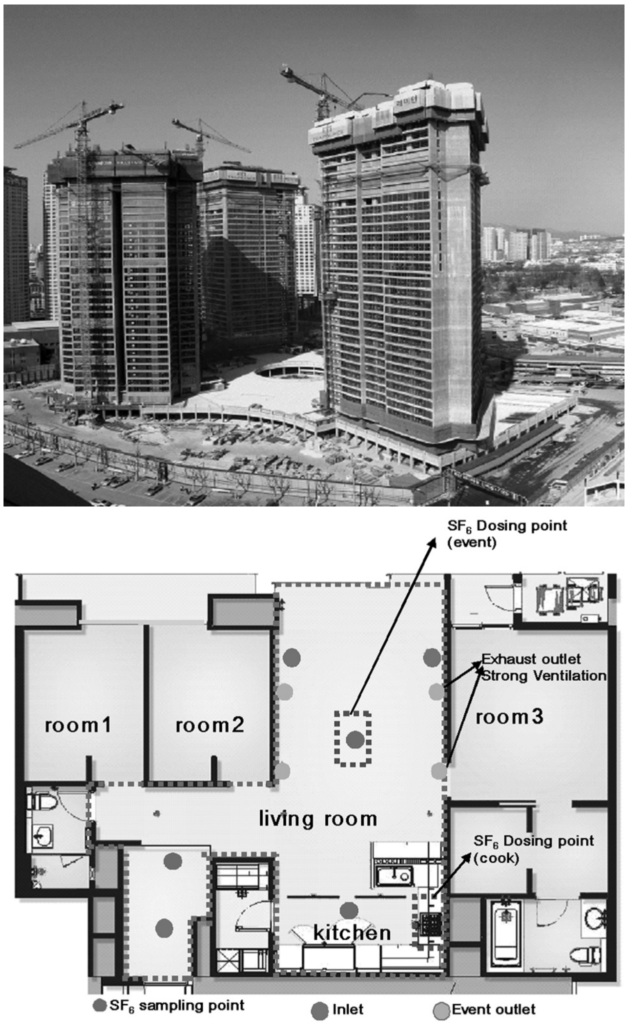


Figure 1: Measurement mock-up building

•acceptability (the degree of pleasantness and unpleasantness of senses),
•quality of the odor (characteristics of the odor),
•detectability (detection probability) must be considered.
However, until now, a precise standard that detects and objectively evaluates the four characteristics mentioned above has not yet been established. In general, an evaluation standard that includes intensity and acceptability as to the content is widely used.
Between the odor intensity and the concentration of cause substances, the following Weber-Fechner law is formed.

Odor intensity = K log C + B (1)

(C: Odor intensity of air, K: Integer of foul odor substance, B: Constant, hypothetical numeric value of odorless concentration)
Equation (1) indicates that even though the concentration of the foul odor substance in the atmosphere might decrease, since the odor intensity that is shown as the size of the sensation is proportional to the logarithm; it does not decrease to the corresponding amount of intensity. It also signifies that to feel that the odor has diminished by half, the concentration must be dropped under 1/10. In reference to the influence of odor on health, experimental results on concentration and intensity of odor have been set to a certain degree, which is not so accurate. The influence of odor intensity on the human body is presented in Table 1. In this research, the odor concentration and intensity of the spread of fish odor ($((CH_3)_3N)$) was analyzed out of the different odors in Table 1.

3. MEASUREMENT

3.1 Abstract of the mock-up building

The mock-up building is located in Seoul and is a reinforced concrete structure that has forty levels above ground and four levels under ground. The mock-up is a household of 155m2 located on the third floor and the plane organization is shown in Fig. 1. The living room faces the southeast direction and one side of the household faces the open air. The ventilation of the mock-up household is accomplished by the diffusers installed in the ceiling. When measuring, the overall construction of the building was in progress, but the household that was measured had its interior finishes completed.

Table 2. The flow rate conditions

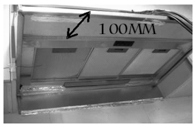
Room name	Supply Inlet	Exhaust Outlet
Room 1	35	-
Room 2	35	-
Room 3	35	-
Living room	120	120
Entrance hall	-	60

Table 3: Out line for experiment

Items	Measurement equipment		Measurement method
	Equipment	Model	
ACH/GAS concentration	INNOVA Multi-Gas Monitor Multipoint Sampler S/W 7620	Type1302(B&K) Type 303(B&K)	Kitchen ventilation system : Gas range on the spread of tracer gas(SF_6) Concentration of Kitchen, Living room, Entrance
Temp/ Humidity	Temp/Humidity Meter	SATO	Outdoor, living room, kitchen, entrance
Temp	GRAPHTEC Data Logger + Thermal couple GRANT Data Logger	GL450 1258 SERIS	Temp, Humidity measurement at 1.5m on the floor Each inlet/outlet air temperature
Infiltration	Blower door	Q52 Blower Door	The constant pressure / Leakage area

Table 4: Kitchen exhaust system, improve of condition

Section	Before	After	Kitchen Item

Kitchen	Hood	400CMH Range: 4holl Hood depths : 550mm	540CMH Range: 4holl Hood depths: 650mm	
	Ceiling exhaust	100CMH	200CMH Soffit install	
	Inlet	400CMH	400CMH	

3.2 Measuring conditions

The measuring period started on February 24 2007 and continued for eight days. The outside temperature of the measuring period was about 12-15ºC, which was comparatively good weather. To maintain the inside temperature at 23-24 ºC, floor radiant heating was in effect. Since actual food odor is formed from many chemical substances and difficulty exists in obtaining measuring equipment, SF_6 gas was used in this experiment. When assuming that SF6 gas and fish odor are all passive contaminants, the spread of fish odor can be grasped indirectly with the concentration of SF6.

The household ventilation was continuously operated throughout the experimenting period, and the measuring was done when the doors were all closed. However, the ventilation in the bathroom was measured when it was not operating. The detailed flow rate conditions of the indoor ventilation system are presented in Table 2. To reduce influences, like the stack effect due to incomplete construction, the experiments for the upper part of the mock-up were carried out by sealing the entrance with tape.

3.3 Measuring methods

For the experiment on the spread of odor during cooking, the constant injection method that discharges 50 ppm of SF6 gas at a fixed rate, and measuring the changes in the gas concentration levles indoors was used. Here, the fish odor around the outlet was assumed as 3ppm, which corresponds to the odor intensity 5 (over strong). Namely, 6% of the SF6 concentration becomes the fish odor concentration. The step down method was used to measure the changes of odor according to time by ventilation. The detailed measuring items and measuring equipment are shown in Table 3, and the producing point and measuring point of the tracer gas are shown in Figure 1. To evaluate the basic airtight capacity of the experiment mock-ups, the infiltration rate and the leakage area were both simultaneously measured.

Table 5. Strong exhaust system

Item	Strong ventilation
Location	Living room
Inlet	Living room window open
Outlet	10 times/h strong exhaust (20mins discharge - 600CMH)

4. IMPROVEMENT OF EXHAUST SYSTEM IN KITCHEN AND PROPOSAL FOR A STRONG EXHAUST SYSTEM

4.1 Exhaust system in kitchens

This research introduces an example that improves the extent that the exhaust system in the kitchen has to reduce the spread of odor when cooking. In households that used the existing exhaust system in kitchens, problems on the spread of odor have already been reported. To improve the exhaust capacity of the kitchen hood, the flow rate of the kitchen hood and the ceiling exhaust were increased by 40%, 200% each (a total of 740 CMH), and the formation of the hood was somewhat modified. Yet, the air supply flow rate was fixed at 400 CMH to control the spread of odor by maintaining a negative pressure compared to the other rooms. Moreover, a soffit was installed on the boundary of the living room ceiling and the kitchen ceiling to prevent the odor from rising with the heated air and moving to another room. A soffit refers to the fence that is installed in the ceiling to prevent the hot odor that is produced when cooking from rising up to the ceiling and spread across the living room. The minute details are presented in Table 4. For the experimental conditions of the exhaust system in the kitchens, based on the existing kitchen ventilation systems (Case 1), the instance where the flow rate of the kitchen hood and the ceiling exhaust system were increased is shown in Case 2, and Case 3 is when a soffit was installed on the ceiling of Case 2. During the actual measuring, water was heated and on so that SF_6 was discharged to reproduce the actual cooking situation.

4.2 Strong exhaust system

In existing research, it is reported that the spread of odor during cooking can be improved to a certain degree by the exhaust system in kitchens, but the spread of odor when eating at the table is difficult to prevent. Therefore, this research suggested a strong exhaust system that can discharge not only the low levels of concentrated food odor that spread during cooking, but also the odors that spread while eating in a short period of time. The strong exhaust system is a system that discharges air corresponding to about 10 times/h of the living room through the exhaust pipe installed in the living room ceiling. It is a method that directly brings in the outside air by opening the windows and doors of the living room. The details related to the strong exhaust system are presented in Table 5. The odor eliminating capacity of the strong exhaust system was measured by using the concentration reducing method. When operating the strong exhaust system, the time it took for the concentration to reduce to 1/10 was evaluated as the capacity of the strong exhaust system. The concentration reducing time was measured by operating the system when the normal conditions were reached by producing SF_6 in the living room.

5. MEASURED RESULTS

5.1 Measured results of the kitchen ventilation system

Numerous difficulties exist in preventing the spread of odor produced when cooking solely with the regular ventilation equipment, since kitchens are in the same space with the living room, not in a separate space. To resolve such a problem, a kitchen system that can collect as much odor as possible at the spot where the odor is produced and then release them, was proposed. The results are shown in Fig. 3.

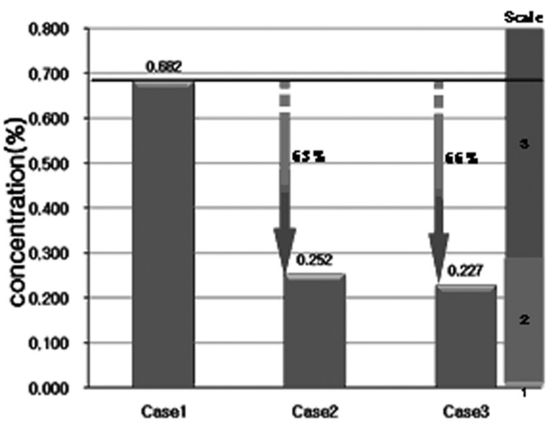


Figure 3: Kitchen ventilation system

It can be understood that the exhaust capacity of the proposed kitchen ventilation system has notably improved the situation compared to that of the extant kitchen ventilation system. When assuming that the concentration near the kitchen table, where the odor develops is 100% (odor intensity 5), about 63% of the effect in preventing the spread of odor was shown in the case of the existing kitchen ventilation system (Case 1) and the improved kitchen ventilation system (Case 2) each showed a concentration of 0.68% and 0.25%. For the odor intensity test, the existing kitchen ventilation system perceived about 3 as a strong odor, but after the improvement, the odor intensity was about 2, which showed that the capacity advanced to a level that can be perceived as a comparatively low odor. For Case 3 that installed a soffit on Case 2, about 3% had improved compared to Case 2, and a great effect was not obtainable.

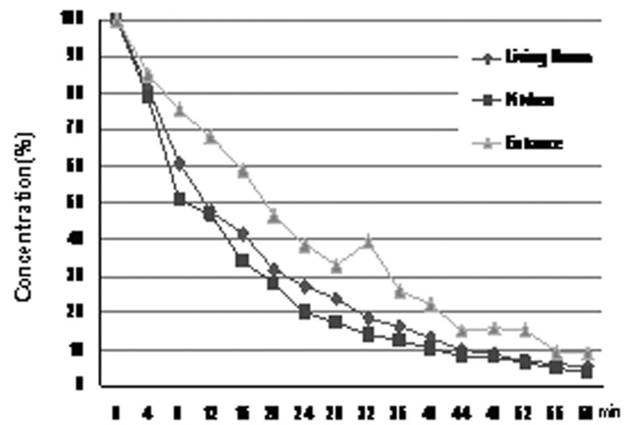


Figure 4: Strong ventilation of concentration

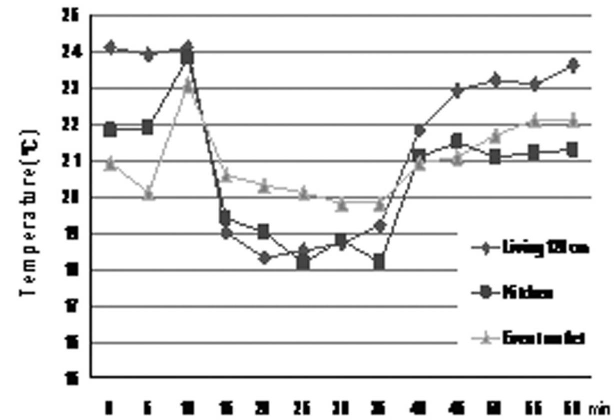


Figure 5: Strong ventilation of temperature

5.2 Measured results of the strong exhaust system

A system that can exhaust strongly (600CMH), which corresponds to 10 times the ventilation, was installed in the living room, and the time for the odor that spread to reduce to 1/10 of its level was measured. The results are shown in Fig. 4. As the concentration of the living room and the kitchen decreased dramatically after about forty minutes after operating the system (the concentration was reduced to 1/10). Concentration reduction at the entrance appears somewhat slower than the living room and the kitchen. It is judged that this is because the inputted outside air does not reach the area near the entrance very well. Furthermore, it is expected to discharge odor more quickly when operating the strong exhaust system and the kitchen exhaust system simultaneously. The inside temperature when operating the strong exhaust system is presented in Fig. 5. It is judged that when operating the strong exhaust system, the indoor heat environment will be greatly affected as outside air is directly brought in by opening the windows and doors in the living room. When the strong exhaust system is in effect, it can actually be observed that the indoor temperature decreases to 6□ at the most. Thus, resolutions related to the unpleasantness of those inside due to temperature decrease and air current by the strong exhaust are demanded.

6. CONCLUSIONS

Along with the improvements in living standards, myriads of related environmental problems are developing with the appearance of high-rise residential buildings. This research proposed a kitchen ventilation system to prevent the phenomenon where odor produced during cooking and eating is not immediately discharged, but spreads to other rooms. Moreover, a strong exhaust system capable of releasing odor in a short period of time, which had already spread, was proposed. The capacity of this exhaust system was measured through experiments, and the following conclusions were obtained.
(1) As a result of increasing the exhaust flow rate and increasing the pile-up area to prevent the spread of odor in the kitchen, the odor concentration in the kitchen was decreased by up to 63%. However, the odor diminishing the effect of the soffit that was additionally installed on the improved kitchen exhaust system was not that great.
(2) The strong exhaust system is effective in exhausting odor in a short period of time and it actually took about 40 minutes to reduce the odor to 1/10 (its original level). However, as the outside air directly brought in can have an effect on the indoor heat environment, related measures are required.

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