Ventilation Control for the Concentration of Fine Suspended Particulate (PM2.5) by Worship Incense

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Abstract. This study analyzed indoor fine particles generated by incense burning. The case study was conducted in a small family chapel. Three different designs of the exhaust system were proposed, including the non-control, the overall ventilation, and the local exhaust scenario. We also took into account the actual human behavior to simulate the concentration changes for various situations. The results showed that the scenario with no fine suspended particles (PM2.5) control had the maximum PM2.5 concentration, exceeding the indoor air quality standards in Taiwan. Although the overall ventilation strategy may reduce the concentration, it may also agitate the environment and disperse the pollutants to the entire room, resulting in a hazy smog condition. This might pose additional threat to people spending time indoor. Finally, using local exhaust plan showed the best PM2.5 controlling efficiency among the three scenarios, while its energy consumption was also the most economical. Nevertheless, different forms of the smoke require different designs of ventilation strategy to obtain the highest efficiency, which was also compared and analyzed in this paper.
1. Introduction

Incense is commonly used in Buddhism and Oriental beliefs. Although families with other beliefs might not use incense, air pollutants caused by incense burning can drift around the atmospheric environment, causing adverse health effects to the local community. Incense produces fine suspended particulate, which contains complex chemical composition. It has become a serious public health problem in most of the Asian countries, including Taiwan. In the study of cancer and epidemiology, the inhalation exposure to incense smoke might be associated with lung cancer, leukemia and brain tumors. Incense contaminants, such as polycyclic aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs) like formaldehyde, may lead to mutagenicity and chromosome mutation. Therefore, controlling worship pollution caused by incense is an urgent problem [1][2][3][4].

Previous research has shown that the reduction of incense pollution can be achieved by using the raw materials with low calorific value, low carbon content, and low volatile matter. However, it is essential to understand pollutants generated during incense burning as long-term exposures to those pollutants are still considered dangerous to human health. In addition, the air pollution control technologies used to remove both gaseous and particulate pollutants are also available. To establish prediction model of pollutants emitting from incense burning and validate it with experimental data is a convenient and practical way for this type of study. The indoor air quality model can serve as a starting point for designing the less-polluting incense. Furthermore, the comparison of the pollutant removal efficiencies for various control technology is also necessary. In this study, the ventilation system for incense burning was chosen as the main examined control technology. The most efficient designing approach for the exhaust ventilation system of a small chapel is discussed thereafter.

2. Research Purpose

The main purpose of this study are as follows:

1. The design of the exhaust system for air pollutants in a small chapel.
2. The design of overall air pollutants ventilation for incense burning.
3. The design of local air pollutants ventilation for incense burning.
4. Comparing the efficiencies of two different types of exhaust method.

3. Experimental Methods

3.1. Study Location
The targeted indoor environment in this study is a family ancestor chapel combined with the worship deity table. This chapel is located in a top floor of the house. There are two censers in the chapel. The incense were burnt at six a.m., noon, and six p.m. Four incenses, three for the incense deity and one for the ancestor chapel, were burnt each time, except for the first and fifteenth day during a month, where twelve incenses in total were burnt.

The experimental site is shown in Figure 1.

![Figure 1. The experiment location.](image)

### 3.2. Overall ventilation

In this study, the overall ventilation design of the chapel is examined first. We used the exit doors as ventilation outlet, where pollutants generated from the incense were removed by natural or mechanical ventilation. Since the chapel is in the middle of two doors and located in the attic, we can use the natural ventilation for exhaust. When using natural ventilation, the air entered from one window and exited from the other.

Since the natural ventilation is facilitated by the atmospheric air change, it cannot take place during calm air situation. Therefore, a mechanical ventilating fan was installed as well. Using a large fan at the height of the window, the air was allowed to enter from the opposite side of the window and discharge by the fan.

### 3.3. Local exhaust

Because the window was very far away from the incense, the local exhaust was installed close to the place of the burning incense, where the suspended particles can be instantly withdrawn and directed to the outdoor, avoiding the hazy smoke. Therefore, this study designed the local exhaust system for the two censers.

### 3.4. Exhaust System
The overall ventilation scenario is illustrated in Figure 2. This ventilation system was installed in the windows right above the door, and it uses two fans for exhausting.

![Figure 2. The overall ventilation system.](image)

The local exhaust is illustrated in Figure 3. This local exhaust system was installed above the incense, where air pollutants were directed by fans immediately after their generations.

![Figure 3. The local exhaust system.](image)

(a)

(b)
4. Results and Discussion

4.1. Results of Natural ventilation

In this study, the first scenario uses the natural ventilation, and the main benefits of this scenario is saving energy. The results of overall ventilation are shown in Figure 4. The disadvantage of natural ventilation is that the wind speed is typically fluctuating. Sometimes it faces the calm condition, and the air pollutants cannot be exhausted into outdoor environment.

4.2. Results of overall ventilation by mechanical exhaust

The overall ventilation by mechanical exhaust equipment can force the particulate into the outdoor atmosphere. However, a major problem took place as it might cause the circulation of the pollutants inside the chapel. The pollutant could be dispersed in the room and form a hazy smoke condition. This is not good for the health of people living in the house.

4.3. Results of local exhaust

The particles can be completely exhausted by the local exhaust system. According to the measured PM$_{2.5}$ concentration, the results of local exhaust system is the most efficient control strategy. The comparison of different scenario is shown in Figure 4.

![Comparison of different control scenario](image)

Figure 4. Comparison of the different control scenario for chapel incense burning.

In Figure 4, scenario A represents the original condition without incense burning; scenario B the concentration after incense burning for one hours; scenario C the concentration by natural ventilation; scenario D the concentration by mechanical exhaust; and finally scenario E represents the concentration controlled by local exhaust system.

5. Conclusion

This study assessed different approach to control the particle concentration in a chapel. Each approach was examined for its ability to remove the particulate matter by measuring the PM$_{2.5}$
when the approach was applied. Three control strategies were chosen, including the natural ventilation, the overall ventilation by mechanical exhaust, and the local exhaust system. The results show that the local exhaust has the highest particle removal efficiency, while the natural ventilation is limited by the atmospheric condition. The overall ventilation by mechanical exhaust may cause the hazy smoke condition, which may compromise its effectiveness in removing particles. Therefore, it is suggested to use the local exhaust system as the best control technology for removing fine particles from incense burning in a chapel inside a family house.

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