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# An experimental study on particle deposition above near-wall heat source

Xi Chen [a, b, *], Angui Li [b]

[a] School of Civil Engineering and Architecture, Henan University of Technology, Zhengzhou, Henan 450001, PR China
[b] School of Environmental and Municipal Engineering, Xi'an University of Architecture and Technology, Xi'an, Shaanxi 710055, PR China

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ABSTRACT

To investigate the effect of near-wall heat sources on the particle deposition, an experiment on particle dimensionless concentrations and size distributions above a near-wall heat source and in the indoor environment is performed. The suspended particles above the near-wall heat source and in the adjacent indoor air are measured and compared. Then the particles are collected under twenty-five different cases by using a Grimm 31-Channel Portable Aerosol Spectrometer. The results reveal that the particles above the near-wall heat source have larger deposition rate than that in the adjacent indoor air. Particles with 0.75 μm–11.25 μm dimension stay more in the air above the heat source than in the adjacent indoor air. We also found that the particle decay rate loss coefficient increases as the heat source surface temperature increases, and it reduces as the gap between the heat source and the wall increases.



## 1. Introduction

Haze pollution recently received a widespread attention as a result of its significant effects on the public health and the visibility [1]. High concentrations of fine particulate matters and the persistence of the episodes have arisen public concerns [2]. The indoor particle concentrations are directly affected by the outdoor particles [3–5] and people spend a considerable amount of time indoors [6,7]. The indoor suspended particles can adversely affect human health. In addition, there are concerns that particles can attract insects and that they have a significant impact on the human health [8]. Airborne particle deposition will cause material damage [9] and disturbance in industries [10]. Thus, it is evident that more attention should be paid to the indoor particles.

Our experiment introduces an effective means for detecting the airborne particles and settled dusts in the indoor environment. Indoor aerosol deposition experiments are always carried out in small chambers or real houses. Many researchers investigated the factors affecting indoor particles, experimentally [11–13]. For example, experiments were performed in a 1.22 m × 1.22 m × 1.22 m aluminum chamber by Thatcher et al., which involved the effects of the particle size, the surface orientation, and the surface-air-temperature difference on the particle deposition velocity [14]. Furthermore, Abadie et al. studied the deposition constants for several wall textures [15]. Moreover, Miller and Nazaroff considered smoker segregation, ventilation modification and air filtration, which were effective on the exposure to airborne particles [16]. Also, Thatcher et al. discussed the particle deposition in an isolated room with different indoor furnishing levels and four different airflow conditions [17]. In the same year, the effects of the surface texture and the airflow condition on the indoor particle depositions were presented by Lai et al. [18].It was found that the ratio of the particle deposition on rough surfaces relative to smooth surfaces increased with the particle size and magnitude of airflow. Following this work, Howard-Reed et al. proposed that the particle size, HAC fan operation and electrostatic precipitator had significant effects on the particle deposition [19]. Particle deposition on the smooth glass plates and the sandpaper were measured with four different roughness scales by Lai and Nazaroff [20]. Their results showed that the particle deposition on smooth and rough vertical surfaces increased with particle size for most conditions. Schnell et al. investigated the particle deposition and distribution in a chamber under both still and stirred conditions [21]. They found that no evident difference between the coagulation coefficient for still and stirred conditions. However, the deposition velocity was higher under the stirred conditions. Hussein et al. investigated the physical characteristics and emission

* Corresponding author. School of Civil Engineering and Architecture, Henan University of Technology, Zhengzhou, Henan 450001, PR China. Tel.: +86 18539968977.
*E-mail address:* chenxiilmmvm@126.com (X. Chen).

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rates of indoor particles during different activities [22]. Later, Kagi et al. reported the impact of the printers on particle emissions [23]. In another experiment, the particle loss rate coefficients on eight coverings were studied by Hamdani et al. [24]. Results showed that the surface three-dimensional roughness was less obvious when particle deposition clearly increased with near-wall airflow velocity. See and Balasubramanian explored the emission factors of $PM_{2.5}$ and its chemical constituents emitted from the incense sticks [25]., Shao et al. recently collected the coal-burning indoor and corresponding outdoor $PM_{10}$ samples and analyzed the relationship between the oxidative capacity of $PM_{10}$ and the lung cancer rate [26].Although many experimental studies have been published concerning indoor particles, little research has been done on particle deposition above near-wall heat sources.

Near-wall heat sources have a large impact on the particle deposition and distribution. Salthammer et al. presented that a large proportion of "Black Magic Dust" phenomenon was found on the wall areas above radiators [27]. The sudden appearances of discolorations on horizontal or vertical surfaces in dwellings were commonly called "Black Dwellings" or "Black Magic Dust" [27]. "Black Magic Dust" was noticed for the first time at the end of the 1980s and it has been increasingly observed since the mid-1990s [28]. In the following years, other scientific literatures on the subject of "Black Magic Dust" were published [29,30]. A series of questionnaire campaigns on the phenomenon of the "Black Magic Dust" were initiated by German Federal Environment Agency between 1997 and 2001. The results showed that the "Black Magic Dust" occurred suddenly, almost exclusively during heating periods [28]. Morawska and Salthammer indicated that the optically visible blackening of the walls was essentially caused by dust particles. Furthermore, the temperature differences determined at the wall surfaces in the investigated housing units possibly led to the "Black Magic Dust" phenomenon [28]. Due to the complexity of this topic, more experiments and investigations are required in order to provide better explanations.

This paper focuses on the effect of near-wall heat sources on the particle deposition. The concentrations of particles and the particle size distributions above a near-wall heat source are studied experimentally. A Grimm 31-Channel Portable Aerosol Spectrometer monitors the suspended particles above the near-wall heat source and in the adjacent indoor air. Also, in twenty-five cases, we measure the particle concentrations above the heat source.

## 2. Experimental methodology

### 2.1. Experimental set-up

Experiments are conducted in a room-sized enclosure, as shown in Fig. 1, with the length of 4500 mm and the width of 3200 mm. During the tests, the room is unoccupied and without mechanical ventilation. All of the building envelope components in this enclosure are either windows or an interior door. Windows and the door are closed in the monitoring process to minimize the effect of the outdoor air and the particle penetration. In addition, the curtain and the windows are closed; also a black paper covers the cracks in order to reduce the sunlight and the infiltration.

#### 2.1.1. Near-wall heat source system

Fig. 2 shows the near-wall heat source system designed for the present study. The heat source system comprises a heating plate, a temperature probe, a temperature control instrument and an alternating current contactor. The details of these instruments are listed in Table 1. The heating plate locates near an interior wall of the room. The lower edge of the heating plate is set to 600 mm high above the floor. The desired temperature is selected via the

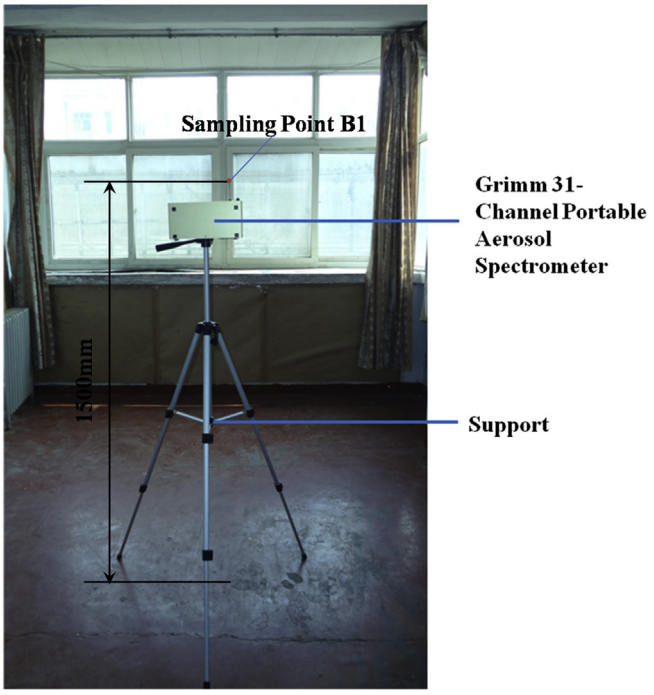


**Fig. 1.** Photograph of the room-sized enclosure.

temperature control instrument. The surface temperature of the heating plate is detected by the temperature probe and then transferred to the temperature control instrument. The temperature control instrument compares the actual temperature with the desired temperature and it outputs the control signals to maintain the heat source surface temperature.

#### 2.1.2. Apparatus and parameters measured

In the present study, a Grimm 31-Channel Portable Aerosol Spectrometer (model No.1.109) is selected for monitoring the particle concentrations and the particle size distributions. The sample air is guided directly to the measuring unit via the inlet. Then, the

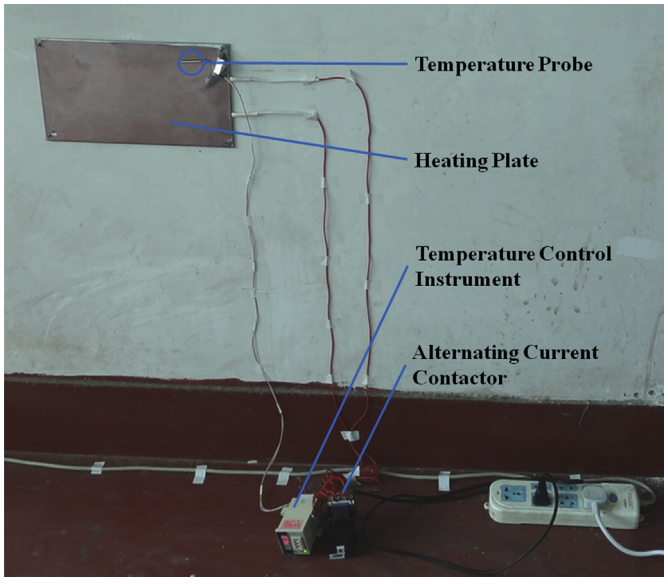


**Fig. 2.** Photograph of the near-wall heat source system.