Journal of Building Engineering 14 (2017) 81–88

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Experimental study of inhalable particle concentration distribution in typical university canteens

Daichao Zhang, Xinming Jin, Lijun Yang*, Xiaoze Du, Yongping Yang

Key Laboratory of Condition Monitoring and Control for Power Plant Equipment of Ministry of Education, School of Energy Power and Mechanical Engineering, North China Electric Power University, Beijing 102206, China

ARTICLE INFO

Keywords:
Particular matter
Number concentration
Mass concentration
Concentration distribution
Canteen

ABSTRACT

Canteens are important places in our daily life, so it is of great significance for human health to investigate the inhalable particle concentration distributions inside them. In this work, the cooking particle concentrations in a typical university canteen with both enclosed and open style cooking units are measured by GRIMM1109, a particle measuring instrument. The results show that the enclosed or open-style cooking plays an important role in the concentration of particles. The particle number concentration is mainly contributed by the particles smaller than 1 μm. For the mass concentration at the same place however, PM_{10} is the top contributor, while PM_1 can be negligible. The particle number and mass concentrations decrease with increasing the distance from the cooking source. The mass concentration of PM_{10} in the open-style cafeteria can arrive at even 0.45 mg/m^3, which is 8.5 times as many as that in the traditional student canteen, and exceeds the maximum allowable concentration of 0.15 mg/m^3. In contrast, the traditional student canteen with the enclosed cooking units is superior to the open-style cafeteria. It is recommended to enhance the ventilation to reduce the harmful effect of particulate matters on human health in the open-style dining hall.

1. Introduction

Haze pollution has become a serious issue for human health, so more and more attentions have been paid to the related researches in recent years, such as the chemical compositions and sources of aerosol particles, aerosol control strategy [1,2]. Atmospheric particulate matter, also called aerosol, is the colloidal dispersion system formed by the solid phase, liquid phase or mixed phase particle dispersion and suspension in the gas. The aerosols can be divided into the total suspended particles (TSP), particulate matter (PM_{10}), fine particulate matter ($PM_{2.5}$), submicron particles ($PM_{1.0}$) and ultrafine particles ($PM_{0.1}$), which have the aerodynamic diameters less than or equal to 100 μm, 10 μm, 2.5 μm, 1.0 μm and 0.1 μm respectively [3]. In general, the formations of haze and fog both depend on the atmospheric aerosol loading and weather conditions [4].

Particulate matter with the size less than 10 μm can suspend in the air for a long time, among which the coarse particle (2.5 μm $\leq d_a \leq$ 10 μm) may deposit in bronchial area of human body and enter the blood circulation, leading to the diseases associated with cardiopulmonary dysfunction [5,6]. Fine particles ($d_a \leq$ 2.5 μm, $PM_{2.5}$) may deposit in the lung, especially respiratory bronchioles and alveoli, which can directly affect the lung ventilation function, or even lead to death. It has been accepted that the fine particles are more harmful to human health than bigger ones, and their health effects warrant further comprehensive assessments [7–9].

Particulate matter exists in various fields such as canteens, which are important places in our daily life, so it is a great concern to study the particulate matter concentration distribution in them. One of the major fine particle sources in urban areas is the release of particulate matter due to cooking food [10]. Most of the particles emitted from meat charbroiling consist of organic compounds, and the emissions depend strongly on the cooking method and food ingredients [11–13]. Gao et al. [14] studied the cooking-generated particles, the major indoor particulate pollutant based on the lab simulation test, finding that the transient space distribution of fume particles is highly dependent upon the source characteristics, and most particles emitting from the rapeseed oil, soybean oil, peanut oil have the size of 2.4–3.0 μm. Wallace et al. [15] found that cooking can produce the ultrafine particles more than 10 times than non-cooking periods. Afshari et al. [16] pointed out that the maximum number concentration of particulates produced by electric roasting can reach 15,0900 cm^{-3}. Li et al. [17] measured the particle size distributions from scrambling eggs, frying chicken and cooking soup in the kitchen using a high resolution particle sizer. Tan et al. [18] adopted the microradiography and Electrical Low

* Corresponding author.
E-mail address: yanglj@ncepu.edu.cn (L. Yang).

http://dx.doi.org/10.1016/j.jobe.2017.10.004
Received 31 May 2017; Received in revised form 23 August 2017; Accepted 8 October 2017
Available online 09 October 2017

Pressure Impactor (ELPI) to measure the oil fume particles, and found the distribution characteristics in the cooking emission of catering industry. Yeung and To [19] found that the normalized number concentration of sub-micrometer aerosols increases rapidly with increasing the cooking temperature, especially in the sizes between 0.1 and 1.0 μm. Ayikezi et al. [20] studied the size-distributions of mineral particles, soot aggregates, spherical particles and other particles (biomass, salt, fibers) in the cafeteria and barbecue restaurant using high resolution field emission scanning electron microscopy (FESEM) and image analysis technologies (IA). By using the Lagrange method, Chung [21] calculated the distribution of the particles in the room. He et al. [22] studied the organic particulate emissions of two cooking styles of Chinese cuisine, that is, Hunan Cooking and Cantonese Cooking. Gupta et al. [23] used a high volume cascade impactor to measure the mass and size distributions of total suspended particulate matter (TSPM) in indoor kitchen environments of five locations in Jawaharlal Nehru University, New Delhi. Su et al. [24] investigated the indoor air pollution of fine particles ($PM_{2.5}$) in the restaurants of Beijing. Wen and Hu [25] studied the PM_1 and $PM_{2.5}$ emitted from the Beijing restaurants by an on-line equipment, finding that the mass concentration of PM_1 is 50–85% of $PM_{2.5}$. From the aforementioned literatures, it can be found that existing studies aimed at the sources of particulate matter in restaurants as well as the physical and chemical properties of the particles, few researches were carried out about the particle distributions in the canteens with various cooking types.

As well known, most of the particle size is between 0.01 and 10 μm in dining rooms [26], however, the main pollutants are PM_{10} [27]. It should be pointed out that the maximum allowable concentration of PM_{10} is 0.15 mg/m^3, but the measurement results show that the PM_{10} concentrations in part of the dining rooms are overweight. With the purpose to clarify the cooking particle type and concentration distribution at dinner time in the typical canteens, the measurements of particulate matters in the open-style cafeteria and traditional student canteen are carried out in this work, which may contribute to the students' health in the dining hall.

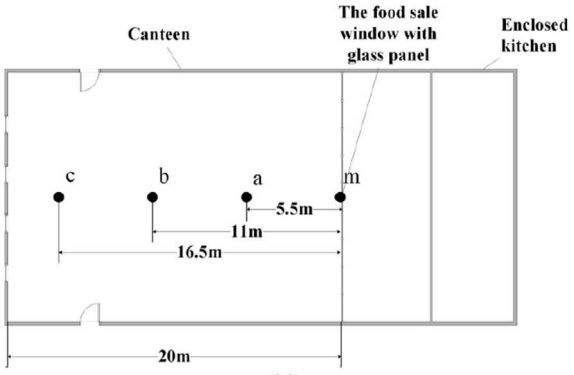
2. Experimental setup

The particle size measuring instrument GRIMM1109 is used to achieve the number and mass concentrations of particulate matter. The measuring particle size falls within the range of 0.25–32 μm, and all aerosol particles passing through the instrument are classified by 31 size distribution channels. As the typical particles, the PM_{10}, $PM_{2.5}$ and PM_1 are mainly investigated. The measuring points are located on the second floor and third floor of a traditional Canteen in a university. On the second floor is a typical Chinese style student canteen as shown in Fig. 1(a), where the glass panel is set in front of the food sale window and the cooking operation is completely enclosed by a kitchen room, so the cooking source has a very little effect on the canteen. On the third floor is an open-style cafeteria as shown in Fig. 1(b), in which the cooking is exposed to the public area, so the cooking source may play an important role in the canteen particle concentration. In order to ensure the accuracy of the experimental data, the sampling is performed in many similar days. Moreover, the confirmatory experiments are also carried out in a few other canteens which have the same style as the above two kinds of canteens.

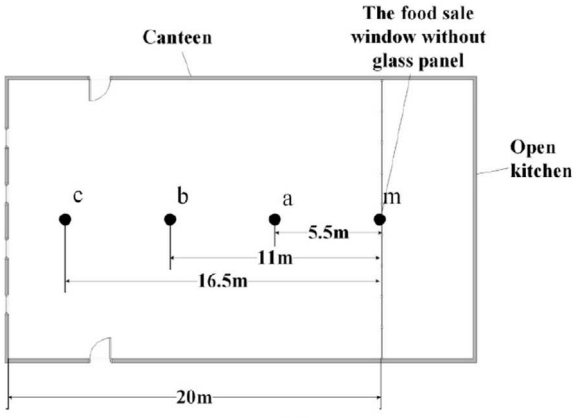
The particle concentrations are measured from 10:30 to 12:30 at lunch time and 16:00 to 18:30 at dinner time from June to August. The measurement in each canteen lasts at least one week to ensure the results more adequate and accurate. The sampling period of instrument is set to 6 s for each time, and a set of data is collected every 1 min to obtain the average value for analysis. One of the measuring points is close to the food sale window defined as point m and the other three points are 5.5 m, 11 m and 16.5 m far from the food sale window respectively, defined as points a, b and c as shown in Fig. 1(c) and (d), which are all set at a height of approximately 1 m above the ground.

(a)

(b)



(c)



(d)

Fig. 1. Different types of Chinese university canteens. (a) Photo of traditional student canteen, (b) photo of open-style cafeteria, (c) schematic of traditional student canteen and measuring points, (d) schematic of open-style cafeteria and measuring points.