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Role of Chinese cooking emissions on ambient air quality and human health

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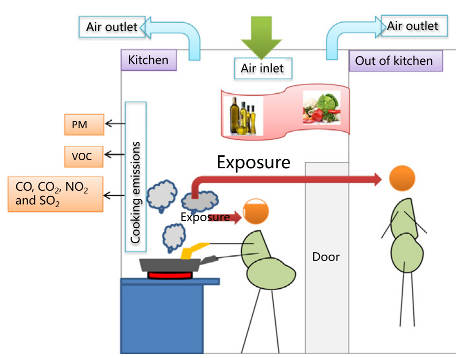
HIGHLIGHTS

- Chinese-style cooking produces large amount of pollutants.
- 79 publications are reviewed and compared. Food material, oil type, cooking style are discussed.
- PM ranged between 0.14 and 24.46 mg/cm^3.
- VOC varied from 0.35 to 3.41 mg/m^{3}PAHs ranged from 0.0175 μg/m^3 to 83 μg/m^3.
- Gaseous pollutants varied between 0.16 to 228.89 mg/m^3.

GRAPHICAL ABSTRACT



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ABSTRACT

Chinese-style cooking often involves volatilization of oils which can potentially produce a large number of pollutants, which have adverse impact on environment and human health. Therefore, we have reviewed 75 published studies associated with research topic among Mainland China, Hong Kong and Taiwan, involving studies on the roles of food ingredients and oil type, cooking style impacting on generated pollutants, and human health. The highest concentration occurred including: 1) when peat, wood, and raw coal were used in stoves; 2) olive oil was adopted; 3) cooking with high temperatures; and 4) without cleaning technology. We conclude that PM concentrations for cooking emissions were between 0.14 and 24.46 mg/cm^3. VOC concentrations varied from 0.35 to 3.41 mg/m^3. Barbeque produced the greatest mass concentrations compared to Sichuan cuisine, canteen and other restaurants. The PAHs concentration emitted from the exhaust stacks, dining area and kitchen ranged from 0.0175 μg/m^3 to 83 μg/m^3. The largest amount of gaseous pollutants emitted was recorded during incomplete combustion of fuel or when a low combustion efficiency (CO2/ (CO + CO2) < 0.5) was observed. The variation range was 6.27–228.89 mg/m^3, 0.16–0.80 mg/m^3, 0.69–4.33 mg/m3, 0.70–21.70 mg/m^3 for CO, CO_2, NO_2 and SO_2 respectively. In regards to the toxicity and exposure, current findings concluded that both the dose and exposure time are significant factors to be considered. Scientific research in this area has been mainly driven by comparison among emissions from various ingredients and cooking techniques. There is still a need for more

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comprehensive studies to fully characterise the cooking emissions including their physical and chemical transformations which is crucial for accurate estimation of their impacts on the environment and human health.

1. Introduction

China has the largest population in the world and its cuisine is one of the world's greatest ones, marked by variety in style and taste. Chinese cuisine is characterized by versatile cooking materials, special seasoning, different cooking techniques and distinctive flavour, which made it very popular around the globe. Chinese cuisine has a number of different styles categorised into the Eight Culinary Traditions of China (i.e. Guangdong (Cantonese), Shandong, Jiangsu, Sichuan, Fujian, Hunan, Anhui and Zhejiang) while the first four are perhaps the best known and most influential.

Cooking emissions are influenced by many factors, such as fuels, cooking oils, food ingredients, duration of cooking period, cooking temperature, cooking styles, ventilations, etc. The contribution of cooking emissions to the overall ambient aerosol was estimated to be between 12% and 20% (Zhu et al., 2014); (Healy et al., 2013). Cooking produces harmful substances including particulate matter (Gao et al., 2013), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAH) (Shen et al., 2012), carbonyl compounds (Cheng et al., 2015). Generally, these substances are present in the air in gaseous or particulate form, depending on environmental factors such as temperature and relative humidity. These compounds have been recognized as significant contributors to ambient haze pollution (Sun et al., 2014). Chinese cooking usually uses oil to scramble or fry food. During this high-temperature cooking process, over 300 types of reaction products are generated including fatty acids, alkanes, alkenes, aldehydes, ketones, alcohols, esters, aromatic compounds, heterocyclic compounds, etc. (Liang, 2004). It not only deteriorates the indoor and outdoor air quality through physicochemical reactions, but also has a considerable harmful impact on human health (Chafe et al., 2014).

Under certain conditions, the material attached to the surface of particles may be absorbed into the human body and consequently have adverse effect on health. Studies have shown that these chemicals exert a lung toxicity, immune-toxicity, genotoxicity and potential carcinogenicity on the body, etc. The potential health hazards often affect people who are subjected frequently to cooking emissions. Experimental studies and surveys found that cooking emission pollutants are likely to have mutagenic and carcinogenic effects, and cooking is regarded as one of the major factors in relation to non-smoking Asian women suffering from lung cancer (Zhao et al., 2007a, b, c; Lam, 2005a, b).

Considering the multiple effects of cooking emissions, Chinese cooking emissions has been a hot research topic for the last two decades. Therefore, this study aims to review the scientific publications published in Chinese and English related to emissions from Chinese cooking which provides a scientific and technological overview with an emphasis on factors impacting cooking emissions as well as the related influence on human health.

2. Research on cooking emissions in China

2.1. A brief research history

Both National Standard of cooking emission GB 18483–2001 and newly-published Shanghai Standard of cooking emission DB31/844–2014 set maximum concentrations allowed (GB 18483–2001_2.0 mg/m^3, DB31/844–2014_1.0 mg/m^3) for total cooking fume and odour as well as minimum removal efficiency of purification facilities.

Fig.1 provides the information of the annual numbers of new studies on Chinese cooking emission published in Chinese and English (the corresponding publication for each paper is written in SI).

Fig.2 summarizes the number of research papers on Chinese cooking emissions. There are numerous Chinese cooking styles which are categorised into eight major cuisines. As Chinese style cooking always produces intense smell and a lot of fume, most urban residents and restaurants use purification equipment in their kitchens (Sun et al., 2015). For that reason, there are more and more studies (Cheng and Hsieh, 2010; Pan et al., 2011) on efficiencies of these purification systems. Furthermore, other factors including oil type, restaurant scale, cooking time, ventilation, food material, temperature, utensils and fuel are regarded as important factors to be considered in the published studies.

Cooking emission studies are mainly conducted in Beijing and Shanghai, as presented in Fig.3. These two cities are the largest cities in China with plenty of catering business on one side and research institutes on the other side. Compared to some other regions in China, Beijing and Shanghai have better conditions to conduct relevant studies. Also, these two cities are under strict supervision of local governments, which set a strict regulation program to mitigate pollution in major Chinese cities. Hong Kong and Taipei conducted several studies in this area, mainly aiming to investigate chemical composition of aerosol and related health effects.

Majority of the studies were conducted in the field (e.g. restaurants, canteens and family kitchens) hence the sampled data are representative of real conditions (fig.4). In addition, there are measurements carried out in the laboratories or lab kitchens, where variables could be controlled and kept at relatively stable values. The emission characteristics can be quantified accurately in laboratory studies which is important for modelling.

The most commonly investigated pollutant components are given in fig.5. In addition, several studies were focused on the risk evaluation associated with pollutants. Each pollutant category presented in Fig. 5 is further discussed in section 2.2.

2.2. Cooking emission characteristics

2.2.1. PM

We conclude that PM concentrations for cooking emissions impacted by various factors were between 0.14 and 24.46 mg/cm^3. Wan et al. (2011) observed that cooking increased the average number concentrations of ultrafine particles (UFPs, particles smaller than 100 nm in diameter) and accumulation mode particles (AMPs) by 10-fold from the background level in the living room and by 20–40-fold in the kitchen. $PM_{2.5}$ mass concentrations increased to the maximum average of about 0.160 mg/m^3 and 0.06 mg/m^3 in the kitchen and living room respectively. Particles from cooking emissions were mainly in the ultrafine size range which contributed the most on particle number concentration. However, AMPs mainly contributed to the mass and surface area by 60% and 73% contribution to the surface area concentrations in the kitchen and living room.

Lin et al. (2014) reported that PM concentration in a cooking fume in typical Shanghai restaurants (Shao Yong, Hong Kong-style, Sichuan, etc.) and Western food, ranging between 0.69–2.60 mg/m^3, PM2.5 was within the range of 0.14–1.67 mg/m^3. The results of Wen and Hu (2007) showed that the sampled $PM_{2.5}$ from a restaurant fume was between 1.382 and 4.053 mg/m^3 in Beijing, which was 8–35 times higher than the ambient atmospheric $PM_{2.5}$ concentration. The highest