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Household air pollution and personal exposure to air pollutants in rural China – A review☆

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ABSTRACT

Solid fuels, an important source of severe Household Air Pollution (HAP) linked to many adverse health outcomes, has been widely consumed around the world. China consumes large amounts of solid fuels and suffers from serious indoor and outdoor air pollution. Though global HAP issues had been reviewed in previous literatures, peer-reviewed Chinese publications were seldom included in those reviews. We conducted a literature review on the studies of HAP and personal exposure in rural China with inputs from peer-reviewed publications in both English and Chinese. A total of 36,572 articles were retrieved, 294 were read in full text, of which 92 were included in final data extraction and in-depth analysis. Although HAP is a very serious issue in China, studies on either HAP or personal exposure assessment were very limited. From existing studies, levels of air pollutants including carbon monoxide, sulfur dioxide, particulate matter (PM), organic carbon, elemental carbon, polycyclic aromatic hydrocarbons (PAHs), etc., in indoor and ambient air were analyzed for their temporal and spatial variations, and the differences across different fuel types were compared. The studies showed that PM and PAHs levels in most rural homes exceeded the World Health Organization (WHO) and Chinese National Standards, especially during the heating season in northern China. Replacing traditional fuels with cleaner ones (such as liquid petroleum gas (LPG), biogas or electricity) was considered as the most appropriate way to mitigate HAP. The daily exposure to PM and PAHs from using LPG, biogas or electricity was considerably lower than that from using traditional solid fuels. However, the level was still higher than the guideline values for PM and PAHs set by WHO to protect human health. To achieve a more effective control, the current data gap need to be closed and suggestions for future research were discussed in this review.

1. Introduction

There are still nearly 3 billion people worldwide relying on traditional solid fuels for cooking and heating. Most of the population are in developing countries, particularly in rural areas with relatively low incomes (Bonjour et al., 2013). Inefficient burnings of these solid fuels produced high emissions of various air pollutants like CO, SO_2, particulate matter (PM), black carbon (BC), polycyclic aromatic hydrocarbons (PAHs), etc., which caused severe pollution in not only indoor but outdoor air (Clark et al., 2013; Chafe et al., 2014). This issue of residential combustion is widely recognized as Household Air Pollution (HAP) nowadays, rather than Indoor Air Pollution (IAP). Inhalation exposure to severe HAP has been documented to be associated with various diseases and premature deaths (Clark et al., 2013; Smith, 1993; Zhang and Smith, 2007; Lim et al., 2012). Globally, around 2.8 million premature deaths were estimated to be due to exposure to HAP, and in China the number was about 1.0 million (Cohen et al., 2017).

There have been several systematic reviews of literatures on HAP and the health impacts (Ezzati and Kammen, 2002a, 2002b; Kim et al., 2011; Mehta et al., 2013; Smith et al., 2000; Zhang and Smith, 2007), on barriers and enablers to promote clean fuels and

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stoves to alleviate HAP problem (Puzzolo et al., 2016; Lewis and Pattanayak, 2012; Rehfuess et al., 2014; Shen et al., 2015), and on changes in HAP and health benefits through interventions (Pope et al., 2017; Quansah et al., 2017). Recognizing that most of these reviews offered the perspective on a global scale, the specific research status in China was brought to our interest.

As the largest developing country, China consumes large amounts of solid fuels such as coals and biomass fuels. Traditional solid fuels are the dominant household energies in most rural areas. The wide use of those solid fuels has contributed largely to indoor and ambient air pollution in the country. Although residential combustion was often overlooked in the air pollution control in China relative to other pollution sources such as power plant and vehicle emissions (Liu et al., 2016), there are growing concerns on HAP and its impacts in China, yielding more publications.

The research questions we started out to form this review were: 1) what's the current status of research on HAP and inhalation exposure measurement in rural China; and 2) what were the range, temporal-spatial variations as well as the differences in groups burning solid fuels (e.g. coal, crop waste, and wood) and non-solid household energies (e.g. biogas, LPG, and electricity) for air pollutants like CO, SO_2, PM, PAHs, etc. For the first question, we were interested to know: how many studies were available in the literature, and when/where these studies were conducted; and, was there an increasing trend in publications on this research topic as the problem gains growing attention among researchers, the public, and the policy makers. In the second question, it was realized that various factors, including fuel type, stove type, burning frequency, household characteristics and ventilation condition, ambient meteorological condition, and other pollution sources, can affect air pollution. In this study, we specifically focused on differences between the traditional solid fuels and non-solid ones, given that many studies and projects were interested in alleviating HAP to protect human health by deploying cleaner fuels into rural homes; and fuel was the most frequently mentioned factor in the literature, while discussions on other influencing factors were limited and only available in few studies. The relatively rich and complete information on fuel allowed us to compile and summarize the data and make comparisons with fairly low bias and uncertainties.

Eligible studies were first identified through a literature search and then subject to screening and full-text evaluation. Quantitative data were extracted and synthesized from final included studies. In this review, we analyzed the research status of HAP and personal measurement in rural China (Section 3.1), characteristics of HAP (including pollution levels, indoor-outdoor difference, seasonal change, and fuel difference) for different pollutants (Section 3.2), and daily exposure to air pollutants (concentration, temporal and spatial changes, and difference in different fuel groups) (Section 3.3). A discussion on the implications and limitations of this review and suggestions on future studies were presented in the last section. In the preparation of this manuscript, we noticed a recently published review by Li et al. (2017) on residential solid fuel combustion in China and its impacts on indoor and ambient air quality. Different from Li et al. (2017) who had main foci on how influencing factors like fuels, stove types, and ventilation conditions, affect air quality by referring to evidences in past studies, the present review extended the literature search to have a compilation on available peer-reviewed publications, in either English or Chinese, on HAP and inhalation exposure studies in rural China. The present study was expected to provide readers a general picture on the research progress of this important topic, and characteristics of air pollution and exposure levels (e.g. pollution levels, seasonal change, and variations in homes using different household energies) in rural China.

2. Method

2.1. Literature search

Standard web-based searches were conducted to access available studies in electronic databases including Web of Science, Science Direct, and Springer Link for English papers, and China National Knowledge Infrastructure, Wanfang Data, and VIP Journal Integration Platform for publications in Chinese. Although a well-structured PICO (Population, Intervention, Comparison, and Outcome) framework may increase precision and satisfaction of searched results, the use of a web-based search interface was acceptable (Booth et al., 2000; Schardt et al., 2007; Cheng, 2004).

The search terms were ("Indoor air pollution" or "household air pollution" or "pollution" or "inhalation exposure" or "portable carried samplers") AND ("solid fuels" or "biomass" or "wood" or "crop residues" or "coal" or "clean fuels" or "clean energy" or "household energy" or "electricity" or "biogas" or "LPG" or "stove" or "cookstove" or "gasifier stoves" or "traditional stoves" or "improved stoves") AND ("China" or "rural China" or "village" or "rural residents" or "rural population") in the TOPIC. The search was done by two reviewers (WD and XL).

2.2. Study selection and data extraction

Only HAP measurements in the rural areas and inhalation exposure for the rural population were included in the present study. The outcome included quantitative measures of daily average concentrations of indoor and outdoor air pollutants in the rural areas, and/or measured or estimated personal exposure to air pollutants. As the review was primarily to understand the status of research and characteristics (e.g. contamination levels, temporal-spatial distribution, and fuel impacts) of HAP and personal exposure studies, there was no restriction on intervention and comparison methods in the literature search. There was also no restriction on the measurement methods, but studies finally included in data extraction must have clear methodology on site information, sampling, quality assurance and controls.

The search yielded a total of 36,572 papers after exclusion of duplicates from the electronic databases. A reviewer (WD) first checked the relevance of these papers by screening titles and keywords. Abstracts of papers that were potentially relevant were then read by three reviewers independently (WD, GS, and YC). Only peer-reviewed publications that were highly relevant to the review scope were downloaded for a full-text review. Any discordant classifications were discussed. To meet the inclusion criteria, the full text of papers must be peer-reviewed, report HAP and/or personal inhalation in rural China, have clear research aims, study design, methodologies and quality controls. This was assessed by three reviewers independently. A flowchart showing search results of identification, screening, eligibility, and inclusion is illustrated in Fig. S1. 92 peer-reviewed papers were finally included and extracted for data analysis in this review.

Data extraction was carried out on all papers that passed selection using the same data extraction form. Information extracted included title, journal, year published, author(s), study year, province/county, site (kitchen, bedroom, or outdoor yard), season, fuel, stove, measurement methodology, number of sample size, pollutant type and statistical results (range, arithmetic mean, median, geometric means, standard deviation, geometric standard deviation) of the HAP and/or inhalation exposure measurements (where applicable). Risk of bias could be from selection bias, study design, con-founders, blinding, data collection, and withdrawals and dropouts. Given the specific objective of the present review, the quality of eligible studies was evaluated for the selection bias