Environment International 106 (2017) 144–152

Contents lists available at ScienceDirect

Environment International

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

# The health policy implications of individual adaptive behavior responses to smog pollution in urban China

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ARTICLE INFO

*Keywords:*
Smog
Air pollution
China
Environmental adaptation
Individual behavior

ABSTRACT

Smog pollution is a serious public health issue in urban China, where it is associated with public health through a range of respiratory and cardiovascular illnesses. Despite the negative health impacts of smog pollution, individual adaptive behaviors are poorly understood. This knowledge gap hinders the development of effective public policy to support and encourage the adoption of individual adaptive and mitigating behaviors to smog pollution. A questionnaire survey of 1141 randomly sampled individuals in a typical $PM_{2.5}$-polluted Chinese city was designed to establish smog concerns and behavior changes during smog events. The results demonstrate a variety of behavior responses associated with risk perception, experience of smog, age, and gender of respondents. An understanding of these variations is critical to the development of effective public policy and ultimately to the improvement of public health in cities affected by smog.

## 1. Introduction

China has one of the highest levels of air pollution in the world (Liu and Diamond, 2005). The prevalence of poor-quality air and its proven links to ill health (Lim et al., 2012; Zhou et al., 2016) are major concerns. In 2010, it was estimated that ambient fine particle matter ($PM_{2.5}$) contributes to > 1.2 million deaths in China annually and to the loss of 24 million healthy years (Lim et al., 2012). In 2013, $PM_{2.5}$ pollution ranked fifth among all contributors to the health burden of the population of China (Zhou et al., 2016). The frequent, large-scale smog pollution caused by $PM_{2.5}$ in urban China has led to social unrest and prompted increasing public demand for regulation to reduce smog and protect public health (Liao et al., 2015; Liu et al., 2016; Zhang et al., 2014). In response, in 2016 the Chinese central government announced its "Ten Measure Air Pollution Control Action Plan" which set a series of strict targets for emissions control, and promoted actions on developing cleaner industrial infrastructure, introducing clean energy practices, and establishing air pollution early warning systems and emergency response plans for smog events. While waiting for controls to take effect to improve ambient air quality (Tanaka, 2015; Wang et al., 2014), urban Chinese citizens have undertaken small-scale personal protective behaviors to reduce the risks of adverse health effects from air pollution (Giles et al., 2011; Laumbach et al., 2015; Rajagopalan and Brook, 2015). The need for policies to facilitate and encourage individual rapid behavioral responses to ambient air pollution has recently become more apparent (Pui et al., 2014).

In light of the importance of encouraging individuals to successfully reduce exposure to air pollution and minimize the related health impacts, this research first addresses the shortcomings in our understanding of individual behavioral responses to air pollution in China and the factors behind different behavioral responses. It then presents the results of a field questionnaire survey conducted during a period of poor air quality in Nanjing. The capital city of Jiangsu Province, Nanjing has a population of over 8 million and is an important center within the highly developed and diversified economy of the Yangtze River Delta region. Due to intensive emissions from industrial and traffic sources, as well as frequent windless atmospheric conditions, in 2013 Nanjing experienced 163 days when the $PM_{2.5}$ concentration was higher than the national air quality standard (75 $\mu g/m^3$) (Nanjing Environmental Protection Agency, 2014). Concentration data from national air pollution monitoring sites No. 1154A and No. 1157A revealed that the average concentration during the survey period (142 $\mu g/m^3$) was more than twice the annual average concentration from January 2013 to December 2014 (69 $\mu g/m^3$).

Individual behavior modification in response to serious air pollution could help reduce individual exposure and protect health (Giles et al.,

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http://dx.doi.org/10.1016/j.envint.2017.06.010
Received 18 September 2016; Received in revised form 9 June 2017; Accepted 11 June 2017

2011). Currently, Chinese government officials at both the central and local levels address individual behavioral modifications only during actual smog episodes. The guidelines broadcast during smog episodes, including changing the timing, location, intensity, and duration of outdoor activities, aim to encourage residents to reduce short-term exposure to poor-quality air. However, the content of these guidelines is vague and overly general and mostly addresses outdoor behavior modification. In addition, there is currently a lack of detailed guidelines for behavioral adaptations to improve indoor air quality and to lower transport emissions to reduce the production of further air pollution.

Despite recent descriptive research into government interest in specific behavioral adaptations, such as reducing outdoor activities (Giles et al., 2011), enhancing indoor protection (Semenza et al., 2008), or changing travel behavior (Elias and Shiftan, 2012), there is limited research describing the full range of individual adaptations to air pollution in China. Importantly, to form the basis for the design and delivery of effective adaptation policies, it is essential to understand the driving factors underlying different behavioral responses. Although previous studies have tried to estimate how individual-level response to smog episodes is affected by various factors, including psychosocial perceptions of air pollution (Elias and Shiftan, 2012; Liobikienė and Juknys, 2016; Semenza et al., 2008), environmental concerns (Garvill et al., 2003), and knowledge of air pollution (Rajagopalan and Brook, 2015), the effects of the interactions among multiple factors have not been formally studied. More importantly, little is known about factors driving changes to individual behavior in response to air pollution specifically within China, where urban residents are frequently exposed to intense air pollution. To provide more substantial evidence to inform effective behavioral intervention and policy-making strategies for appropriate response and mitigation, it is critical to improve understanding of the overall mechanisms that influence individual behavior.

## 2. Methods

### 2.1. Questionnaire survey

The aim of the questionnaire survey was to examine changes in individual behavior coping with smog pollution episodes. A smog pollution episode is defined here as a day categorized by the national daily weather forecasts as “smog day” or “heavy pollution”. This is a common way for urban residents to recognize smog and, therefore, for respondents to understand questions regarding behavior changes during smog episodes.

The face-to-face questionnaire survey was performed on a random sample of 1200 individuals in Nanjing during a heavily polluted period between December 2013 and January 2014. The average $PM_{2.5}$ concentration exceeded the standard limitation concentration on 52 of the 62 survey days (a rate of 83.8%), indicating frequent, serious pollution conditions in Nanjing throughout the period (Fig. A.1, Appendix 1). Thus, the timing of the survey may provide a suitable opportunity to measure more real individual perceptions and accurate recollections of behavioral changes in reaction to smog episodes, as the survey covered an entire severe pollution period, under which respondents' feelings and experiences about smog pollution were current and ongoing.

Where population information was available for a given urban area, a three-step sampling method was adopted (see Appendix 2). Inclusion criteria included those aged 16 years and over and resident in Nanjing for at least one year. Structured and anonymous interviews were conducted with each individual participant, all of whom provided written informed consent. Researchers and research-trained staff from Nanjing Disease Control and Prevention Center (CDC) conducted the field survey.

After exclusion of incomplete questionnaires and those with missing values and logical errors, valid responses were ultimately obtained from 1141 respondents, an effective response rate of 95.1% (1141/1200). The sample structure is shown in Table 1, with a comparison to the city population structure in parentheses (local income information was unavailable due to data limitation). The sample matched the local population structure closely with respect to gender and age, while respondents' education levels were higher than the average level of the city population. This pattern was also observed by Huang et al. (Huang et al., 2013) in their study of risk perception. This educational bias might be attributed to less well-educated residents experiencing greater difficulty in understanding survey questions and, therefore, returning incomplete questionnaires (Huang et al., 2013).

**Table 1**
Sample description.

| Basic information | Groups | Percentage |
|---|---|---|
| Gender | Male | 50.0% (51.7%) |
| | Female | 50.0% (48.3%) |
| Age (years old) | 16–34 | 39.3% (39.9%) |
| | 35–44 | 23.0% (17.5%) |
| | 45–59 | 25.2% (20.8%) |
| | ≥ 60 | 12.5% (13.7%) |
| Education (years) | ≤ 6 | 11.2% (19.2%) |
| | 6–9 | 12.1% (29.6%) |
| | 9–12 | 27.2% (20.8%) |
| | > 12 | 49.5% (26.1%) |
| Income (CNY/month) | 0–700 | 2.3% |
| | 700–1400 | 6.2% |
| | 1400–5000 | 67.6% |
| | 5000–10,000 | 21.3% |
| | > 10,000 | 2.6% |

The questionnaire was made up of three parts. The first part, consisting of nine questions, addressed individual perceptions of smog pollution and its related health effects, and was designed based on the psychometric paradigm method (Slovic, 1987), which uses scaled questions to measure individual preferences with respect to different risks (Siegrist et al., 2005; Slovic, 1987; Tam and McDaniels, 2013). Each question measured perception levels by asking respondents to provide a score ranging from 1 to 7 for each question (see Table A.1, Appendix 3).

The second part, consisting of ten questions, measured individual behavioral changes during smog pollution episodes. Behavioral change was described using a four-point scale, where 4 represented an increase in behavior, 3 represented no change in behavior, 2 represented reduced behavior, and 1 represented behavior in which the participant never engaged regardless of air pollution levels (“I never do it”). The questions in this section dealt with four behavior categories: (1) concern behaviors, including interest in weather forecasts, causes of smog, and health protection guidelines; (2) normal daily activities, including changes in duration and intensity of outdoor activity and indoor ventilation; (3) additional protective behavior, i.e., wearing professional anti-pollution masks and the use of household air purifiers; and (4) transport patterns, particularly concerning car use.

The third part of the questionnaire, consisting of seven questions, surveyed demographic information and individual self-reported experiences of suffering from air pollution (0 = never experienced, 1 = experienced), as well as health status on the day of the survey (0 = not comfortable, 1 = comfortable).

### 2.2. Statistical models

Descriptive statistical data are presented here to show general