Environmental Research 157 (2017) 78–86

Contents lists available at ScienceDirect

Environmental Research

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

A comparison of individual exposure, perception, and acceptable levels of $PM_{2.5}$ with air pollution policy objectives in China

Lei Huang[a,b,*], Chao Rao[a], Tsering Jan van der Kuijp[c], Jun Bi[a,*], Yang Liu[d]

[a] State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Xianlin Campus, Box 624, 163 Xianlin Avenue, Nanjing 210023, China

[b] Lamont-Doherty Earth Observatory, Columbia University, P.O. Box 1000, 61 Rt. 9W. Palisades, NY 10964, USA

[c] Department of Environmental Science and Public Policy, Harvard University, Cambridge, MA 02138, USA

[d] Department of Environmental Health, Rollins School of Public Health, Emory University, Atlanta, GA 30322, USA

ARTICLE INFO

Keywords:
Atmospheric pollution
Risk perception
$PM_{2.5}$ exposure
PARL
Action Plan

ABSTRACT

Atmospheric pollution has emerged as a major public health issue in China. Public perception and acceptable risk levels of air pollution can prompt individual behavioral changes and play a major role in the public's response to health risks. Therefore, to explore these responses and evaluate what constitutes publicly acceptable concentrations of fine particulate matter ($PM_{2.5}$), questionnaire surveys were conducted in three representative cities of China: Beijing, Nanjing, and Guangzhou. Great differences in public risk perception were revealed. Public perception of the health effects of air pollution (*Effect*) and familiarity with it (*Familiarity*) were significantly higher in the winter than in the summer, and also during severe haze days compared with typical days. The public perception of trust in the government (*Trust*) was consistent across all conditions. Exposure to severe haze pollution and experiencing harms from it were key factors influencing public willingness to respond to haze. These results reflected individual exposure levels correlating closely with risk perception and acceptance of $PM_{2.5}$. However, a crucial gap exists between public acceptable risk levels (PARL) of air pollution and the policy objectives of the State Council's Action Plan. Thus, policymakers can utilize this study to develop more targeted measures to combat air pollution.

1. Introduction

Over recent decades, China has been experiencing rapid economic growth. However, high-speed economic growth along with unprecedented increases in energy consumption and emissions of air pollutants also aggravate the severity of air pollution in China (Badland and Duncan, 2009). Numerous epidemiological studies have established that fine particulate matter is one of the most hazardous studied pollutants given its impact on long-term mortality regarding respiratory and cardiovascular diseases (Brook et al., 2004; Brunekreef, 2002; Kunzli et al., 2000; Sicard et al., 2011). Of all the most common detrimental air pollutants, $PM_{2.5}$ is believed to be the most serious pollutant due to its harmful health impact on the cardiovascular, respiratory, and pulmonary functionality in humans (Han et al., 2015; Lai et al., 2016).

In response to the current severe air pollution situation, the State Council in China issued its Action Plan on Prevention and Control of Air Pollution (the "Action Plan"),(CAAC, 2013) in which the concentration of $PM_{2.5}$ in Beijing, Nanjing, and Guangzhou cities should be reduced by 25%, 20%, and 15%, respectively, between 2012 and 2017. Understanding public perception and acceptable levels of air pollution could help to verify the reasonableness and effectiveness of the policy as well as guide the communication frameworks to achieve the desired change in public attitudes and behavior (Eden, 1996; Muindi et al., 2014). However, current information concerning urban air quality in China derives mainly from measurements at monitoring stations, with little attention being paid to public sentiment and subjective perceptions of air pollution (Brody et al., 2004). Moreover, it is vital for the individuals to understand and predict the consequences of environmental contamination (Stenlund et al., 2009; Zhou et al., 2015). Additionally, it was shown that compared to air quality monitoring, personal perception of air quality affects self-reported health conditions

Abbreviations: $PM_{2.5}$, particles with aerodynamic diameter less than 2.5 µm; ADD, average daily $PM_{2.5}$ exposure; *Effect*, the public perception of the health effects of air pollution; *Familiarity*, the public perception of familiarity with air pollution; *Trust*, the public perception of trust in the government; PARL, public acceptable risk level; *SHE*, severe haze experience; *HEDTH*, harms experienced due to haze

* Correspondence to: School of the Environment, Nanjing University, Xianlin Campus, 163 Xianlin Avenue, Nanjing, China.
E-mail addresses: huanglei@nju.edu.cn (L. Huang), jbi@nju.edu.cn (J. Bi).

http://dx.doi.org/10.1016/j.envres.2017.05.012
Received 20 March 2017; Received in revised form 5 May 2017; Accepted 9 May 2017
0013-9351/

to a greater degree (Piro et al., 2008; Yen et al., 2006). Perception is also an important component in facilitating behavioral changes and plays a major role in the public's response to health risks (D, 2012; Elliott et al., 1999; P.; et al., 2009). Furthermore, people's behavior and response to preventive measures depends on the way they perceive environmental stimuli, therefore, it's crucial for policy officials to consider people's perceptual and behavioral changes so as to protect public health through adaptive measures (Berry et al., 2011; Elliott et al., 1999).

The general public may perceive the health risks of air pollution differently on account of various demographic characteristics (Riddel and Shaw, 2006; Shaw and Woodward, 2008). For example, women usually perceive higher levels of air pollution risk than men (Forsberg et al., 1997; Jacquemin et al., 2007; Williams and Is, 1995). Age was found to be related to air pollution risk perception as well (Seo and Barrett, 2007; Van et al., 2008); for instance, Kim and Fischer et al. have indicated that young people are more sensitive to air pollution risks (Kim et al., 2012), while the elderly pay more attention to health and safety (Fischer et al., 1991). Forsberg and Williams et al. have discovered a higher risk perception of air pollution among middle-aged people (Forsberg et al., 1997; Williams and Is, 1995). Further to that point, individuals with higher levels of education and income are expected to be more concerned about air pollution, as these factors could provide them with resources to understand the impacts of air pollution on their lives (Egondi et al., 2013; Jacquemin et al., 2007; Kim et al., 2012; Seo and Barrett, 2007). Conversely, Geelen, Klælboe and Semenza et al. found that people with lower income and education levels might have more complaints about air pollution (Geelen and Souren, 2013; JC et al., 2008; Klælboe et al., 2000). Factors such as marriage were likewise related to air pollution risk perception (Egondi et al., 2013; Kim et al., 2012). In addition, air quality perception could also be influenced by psychological and physical experiences, health and lifestyle factors (e.g., time spent outdoors)(Brody et al., 2004; Nikolopoulou et al., 2011), as well as temperature variations and thermal sensations during different seasons (Dorizas et al., 2015; Zhang et al., 2011).

Examining individual perception towards air pollution could reflect the social dimensions and circumstances under which people understand pollution (Kunzli, 2003). Moreover, effective risk communication could also strengthen public awareness about health risks, increase trust in government, and reduce their anxiety about air pollution (Geelen and Souren, 2013; Sjöberg, 2004). To our knowledge, this is the first study to explore the public risk perception of air pollution by comparing three representative major cities in China. Few studies, if any, have been conducted to calculate the PARL of air pollution to uncover the factors underlying public perception towards pollution exposure. These factors trigger individuals' preventive actions and responses to air pollution, daily exposure to $PM_{2.5}$ (ADD), and overall health.

We conducted a comprehensive analysis to explore the influencing factors on public risk perception of air pollution in three major cities in China. The objectives of this study are 1) to explore the determining factors influencing public risk perception of haze by combining multi-city results, 2) to determine the relationship between ambient levels of haze and public perception, 3) to identify sensitive subpopulations behind the public perception of air pollution effects and their preventive actions, and 4) to evaluate PARL of $PM_{2.5}$ to test the reasonableness of the Action Plan issued by the Chinese government.

2. Materials and methods

2.1. Study site

Ongoing industrialization has increased air pollution and induced continuous haze across the country, especially in the Beijing-Tianjin-and-Hebei Region, Yangtze River Delta, and Pearl River Delta. Beijing city as the capital of China, Nanjing city as the political and cultural center of Jiangsu province, and Guangzhou city as the capital of Guangdong province were selected as the representative cities of the above regions in our study, as seen in Fig. 1 plotted using ArcGIS 10.20 software.

2.2. Sample selection

Our surveys covered a total of 1500 randomly stratified sampled residents in the above cities, with1284 valid questionnaires returned. The first round of surveys was administered to Beijing, Nanjing, and Guangzhou residents in July 2013, covering 250, 500, and 250 adults respectively; a total of 887 questionnaires (243, 407, and 237, respectively) were returned with a response rate of 88.7%. Considering the influence of seasonal factors on public risk perception towards haze pollution, we carried out the second round of surveys in December 2013 in Nanjing, which has four distinctive seasons and the most haze-polluted days among the above three cities in 2013. This investigation covered 500 adults over the winter with 397 questionnaires returned (including 158 samples collected during severely hazy days). All respondents were interviewed face-to-face by senior students from the Nanjing University School of the Environment who had been well trained in survey techniques. As seen in **Table S1–S3**, the survey respondents were similar to the city's population in terms of sex, occupation, and monthly income. The respondents were more educated than the rest of the city, which phenomena were also found in other studies (Geelen and Souren, 2013). This might be attributed to the fact that uneducated people are more likely to have difficulty understanding survey questions and cannot complete a questionnaire easily. In general, the sampling biases resulting from these differences are small and negligible.

2.3. Questionnaire

The questionnaire was designed based on psychometric paradigm methods, (Huang et al., 2013; Sjöberg, 2000; Slovic, 1987) with minor modifications based on Chinese residents' living situations (e.g., education levels, and income levels). The questionnaire mainly consisted of four sections, which is shown in Supplementary Information. The first section included 13 questions corresponding to three dimensions of risk perception to measure public perception regarding haze pollution. The response to each question was ranked on a 5-point Likert-type scale ranging from "1 = minimum" to "5 = "5 = maximum". The second section included an introduction to the Action Plan and some questions to measure the respondents' acceptance of the $PM_{2.5}$ concentration reduction plan. The third section investigated the respondents' daily time-activity patterns. Respondents were asked to recall their activities during the usual 24 h in detail. The last section of the questionnaire was designed to collect the respondents' demographic characteristics (including age, gender, education, income, marital status, and smoking status), preventive actions taken, previous severe haze experience (*SHE*), and harms experienced due to haze (*HEDTH*). The last two variables referred to their experiences of psychological and physical effects or impacts on health from haze pollution.

2.4. Risk perception analysis

Risk perception factors included three categories defined as *Effect*, *Familiarity*, and *Trust*. As shown in Supplementary Information Part I, the topic in questions 3–9 corresponds to *Effect*, the topic in questions 1 and 2 corresponds to *Familiarity*, and the topic in questions 10–13 corresponds to *Trust*. The confirmatory factor analysis was conducted using Lisrel 8.70 software, while the independent-samples *t*-tests conducted using SPSS 22.0 software were used for comparison analysis of the risk perception factors in different areas, seasons, and air-polluted days.