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Can the Air Pollution Index be used to communicate the health risks of air pollution?

Li Li [a], Guo-Zhen Lin [b], Hua-Zhang Liu [b], Yuming Guo [c], Chun-Quan Ou [a,*], Ping-Yan Chen [a,*]

[a] State Key Laboratory of Organ Failure Research, Department of Biostatistics, Guangdong Provincial Key Laboratory of Tropical Disease Research, School of Public Health and Tropical Medicine, Southern Medical University, Guangzhou 510515, China
[b] Guangzhou Center for Disease Control and Prevention, Guangzhou 510440, China
[c] Division of Epidemiology and Biostatistics, School of Population Health, The University of Queensland, Brisbane, Queensland 4006, Australia

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ABSTRACT

The validity of using the Air Pollution Index (API) to assess health impacts of air pollution and potential modification by individual characteristics on air pollution effects remain uncertain. We applied distributed lag non-linear models (DLNMs) to assess associations of daily API, specific pollution indices for PM_{10}, SO_2, NO_2 and the weighted combined API (APIw) with mortality during 2003–2011 in Guangzhou, China. An increase of 10 in API was associated with a 0.88% (95% confidence interval (CI): 0.50, 1.27%) increase of non-accidental mortality at lag 0–2 days. Harvesting effects appeared after 2 days' exposure. The effect estimate of API over lag 0–15 days was statistically significant and similar with those of pollutant-specific indices and APIw. Stronger associations between API and mortality were observed in the elderly, females and residents with low educational attainment. In conclusion, the API can be used to communicate health risks of air pollution.

1. Introduction

The detrimental effects of ambient air pollution on environment, climate and public health have been recognized (Azmi et al., 2010; Shah et al., 2013). Air pollution remains a critical global health and justice problem. A significant proportion of premature deaths and admissions may be avoidable by reducing air pollution (EPA, 2011; Li and Gibson, 2014; Tang et al., 2014).

To provide easy public access to current air quality information, the Chinese government delivered the real-time daily data of Air Pollution Index (API) during the period before 2012. And a modified index, the Air Quality Index (AQI) has replaced API since then. Data of daily concentrations of specific air pollutants, however, is available to the public only in a limited number of cities. Most of the countries which deliver air quality information to the public report pollution indices instead of concentrations of specific pollutants. Hence, compared to concentrations of specific air pollutants, indices such as the AQI/API are more familiar to the public and more significant in the public health context. Despite intense studies on the health effects of specific air pollutants (Dong et al., 2012; Hu and Rao, 2009; Kong et al., 2015), there are relatively few studies evaluating the validity of using index to examine the associations between air pollution and health. Among these limited studies, Poursafa et al. (2011) and Rashidi et al. (2013) evaluated the associations of the Pollutant Standards Index (PSI) with hematologic parameters and respiratory diseases in Iran, respectively. Poursafa et al. (2014) revealed the associations of AQI with cardiometabolic risk factors in Iran. In the USA, Grant (2009) showed a significant association between state-averaged cancer mortality rates and API for the periods 1950–1969 and 1970–1995. Health Canada and Environment Canada developed the Air Quality Health Index (AQHI) on the basis of health effect estimates of individual pollutants. To et al. (2013) reported the associations between AQHI and asthma morbidity in Ontario, Canada. Similarly, Chen et al. (2013) examined the associations of AQHI with mortality and morbidity in Shanghai, China. The findings of these studies suggest that the AQI/API may be used to communicate the adverse effects of air pollution on public health, while the associations between daily variations in AQI/API and daily changes in mortality have not been

* Corresponding authors.
E-mail addresses: ouchunquan@hotmail.com (C.-Q. Ou), chenpy99@126.com (P.-Y. Chen).

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well examined. Results based on the direct analyses of AQI/API are much easier for the public to understand the health risks associated with air pollution. It is also helpful for health education and health promotion for the general population.

It has been recognized that air pollution had lagged effects on health. Existing studies generally assessed the air pollution effects in no more than one week. To response the argument that the deaths caused by air pollution reflect solely the harvesting (mortality displacement) of individuals who would have died a few days later even without pollution, some investigators tested the "harvesting only hypothesis", indicating that harvesting did not play a major role in the effects of air pollution (Schwartz, 2000; Zeger et al., 1999). Detecting the harvesting and assessing the overall health effects of air pollution require broader time windows.

It has been shown that some subpopulations such as the elderly are more susceptible to the effects of air pollution (Bateson and Schwartz, 2004; Chen et al., 2012; Kan et al., 2008; Wong et al., 2008; Yu et al., 2012; Zeka et al., 2006). But the role of socioeconomic status (SES) in the vulnerability to air pollution remains inconsistent in previous studies. Particularly, vulnerability remains uncertain regarding the API-mortality relationship.

Guangzhou is the transportation, industrial and trade center of southern China. Like other metropolises, Guangzhou is suffering from air pollution. The present study aimed to evaluate the validity of using API to communicate the health risks of air pollution and assess the time course of the API-mortality association in Guangzhou, China, during 2003–2011. The subpopulations particularly vulnerable to air pollution will be further identified.

2. Methods

2.1. Data

Guangzhou, a city having a typically subtropical climate, is the largest metropolis in southern China with the latitude of 23°07′ N. There are over 12.7 million permanent residents in Guangzhou according to the Sixth National Population Census of China. We obtained individual data for all registered deaths at six urban central districts in Guangzhou between 1 January 2003 and 31 December 2011 from Guangzhou Center for Disease Control and Prevention. The underlying causes of death were coded according to the International Classification of Diseases, the tenth version (ICD-10). Non-accidental (ICD-10: A00-R99), cardiovascular (ICD-10: I00–I99) and respiratory (ICD-10: J00-J99) mortality were examined. Non-accidental deaths were stratified by age (<65 and ≥65 years), gender, educational attainment (low educational attainment was defined as illiterate or primary school; high educational attainment as middle school or above) and occupation class (white-collar workers, blue-collar workers, and the unemployed including housewives).

Daily meteorological data on mean temperature, relative humidity and atmospheric pressure were obtained from China Meteorological Data Sharing Service System. Weather data were collected from Guangzhou Weather Station, which is the only basic weather station in Guangzhou, as part of the global meteorological information sharing network.

Guangzhou Bureau of Environmental Protection provided daily air pollution data on API. In this study, we selected seven fixed-site air monitoring stations as they had valid daily measurements for the entire study period. Details for monitoring stations were described in our previous studies (Ou et al., 2013; Li et al., 2014). The average daily concentrations of three pollutants (i.e., PM_{10}, SO_2, and NO_2) in the entire territory of Guangzhou were computed using the centering method (Wong et al., 2001). The method of linear interpolation was used to calculate the API (U.S. Environmental Protection Agency, 2006), specified as:

$$API_i = (API_U - API_L)/(C_U - C_L) \times (C_i - C_L) + API_L$$

$$API = \max(API_i)$$

where API_i is the index for pollutant i (i.e., PM_{10}, SO_2, and NO_2). A daily index is calculated for each air pollutant. C_i is the observed concentration of pollutant i. C_U and C_L are the upper and lower limits of the interval (see Supplemental Material, Table 1), within which lies the C_i. API_U and API_L are the upper and lower limits of the corresponding API interval. The API is defined as the maximum of API_i, and the pollutant responsible for the highest index is the "Main Pollutant", if the API is above 50.

2.2. Statistical analysis

Spearman correlation coefficients of daily API and pollutant-specific indices were firstly calculated. Then, a weighted combined API (APIw) was constructed as follow:

$$APIw = \sum w_i API_i \quad \sum w_i = 1$$

where w_i is the weight for index for pollutant i (i.e., PM_{10}, SO_2, NO_2). The weight for the "Main Pollutant" (i.e., w_M) was set to be 1/3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and the weight for other two pollutants was $(1 - w_M)/2$.

Quasi-Poisson regression models combined with distributed lag non-linear models (DLNMs) were used to examine the associations of API, indices for PM_{10}, SO_2, NO_2 and APIw with non-accidental mortality. We controlled for long-term and seasonal trends using a nature cubic spline for time with 7 degree of freedom (*df*) per year

Table 1
Summary statistics for pollution indices, mortality and daily weather conditions in Guangzhou, China from 2003 to 2011.

Variables	Mean ± SD	Minimum	Percentile			Maximum
			25th	50th	75th	
API	66 ± 25	13	50	62	78	229
Index for PM_{10}	64 ± 25	7	49	61	76	229
Index for SO_2	42 ± 23	2	23	41	58	113
Index for NO_2	45 ± 26	11	27	37	51	200
Daily number of deaths						
Non-accidental	63 ± 14	20	53	60	70	233
Cardiovascular diseases	24 ± 7	6	19	23	28	102
Respiratory diseases	12 ± 4	2	9	11	14	46
Mean temperature (°C)	22.7 ± 6.3	5.4	18.3	24.2	27.8	34.2
Mean humidity (%)	71.4 ± 13.0	20.0	64.0	73.0	81.0	99.0
Mean pressure(hpa)	1008 ± 7	989	1003	1008	1013	1027