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Urban air quality evaluations under two versions of the national ambient air quality standards of China

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ABSTRACT

The air quality of urban areas is of a great concern for residents living in cities. China has released a new National Ambient Air Quality Standard (NAAQS) in 2012 to improve the air quality evaluation index because the reported air quality situation from governments is inconsistent with public sensing. In total, 190 cities' hourly monitoring data are publicized in the national web platform. By using the above data, the air pollution indexes (APIs) under the previous NAAQS and air quality indexes (AQI) for all 190 cities' were calculated. With the new NAAQS, the national attainment rate has fallen from 73.63% to 59.62% with regional differences. 8 of the 10 cities with the worst air quality are located in North China around Beijing, while 9 of the 10 cities with the best air quality are located in South China. These results indicate that cities in North China, including Beijing, need to address the air pollution together as the pollution in North China is a regional issue and not a local issue.

1. Introduction

Air pollution has become a major problem for residents living in urban areas in China, especially those cities in North China experiencing several severe fog-haze events during the winter and early spring (Sun et al., 2006). The major pollutants in urban areas include PM2.5 (particulate matter with aerodynamic diameter less than or equal to 2.5 μm), PM10 (particulate matter with aerodynamic diameter less than or equal to 10 μm), ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, etc. (Xu et al., 2013; Clark et al., 2014) PM10 is mainly from smoke, road dust and pollen, while PM2.5 is mainly from dust, coal combustion, biomass burning, traffic, etc., considering different local atmosphere environments (Zhang et al., 2013). The remaining 4 air pollutants are also mainly from human activities: vehicle exhaust, heating plants, etc. (Wang et al., 2013; Wei et al., 2014; You, 2014) Numerous studies have investigated the relationship between PM2.5 concentration and respiratory diseases (Schwartz and Neas, 2000), asthma (Gavett and Koren, 2001), cardiopulmonary mortality (Pope et al., 2002), and other health diseases (Nel, 2005; Kan et al., 2007; Krishnan et al., 2012; Janssen et al., 2013; Leiva et al., 2013). For example, long-term exposure to high concentrations of both PM2.5 and PM10 will probably increase the risk of morbidity and mortality for humans (Du et al., 2010). As a result, the World Health Organization has announced standards for daily and annual PM2.5 concentrations for the local government to evaluate and improve atmospheric conditions. Under this standard, a daily average PM2.5 concentration of 75 $\mu g/m^3$ and an annual average PM2.5 concentration of 35 $\mu g/m^3$ are recommended for Interim target-1 stage. The recommended safe air quality guidelines of the daily and annual average PM2.5 concentrations are 25 $\mu g/m^3$ and 10 $\mu g/m^3$ respectively (Leiva et al., 2013).

China has been monitoring the ambient atmosphere since the 1980s. Beginning in 1998, the Chinese government began to report the weekly air pollution index (API) by considering the total suspended particle (TSP), nitrogen oxide, and sulfur dioxide concentration. Beginning in June 2000, major cities in China began to report daily API with daily measurements of PM10, nitrogen dioxide, and sulfur dioxide under the request of former State Environmental Protection Agency of China (now the Ministry of Environmental Protection of China) (Wang et al., 2013; Xia et al., 2014).

A national ambient air quality standard of China was released in 1996 (NAAQS-1996) to define API calculation. Under this NAAQS-

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1996, daily API values that were less than or equal to 100 and a PM10 concentration of less than or equal to 150 $\mu g/m^3$ are considered to represent attainment days. The number of attainment days in a year is an important index to evaluate the environmental work of local governments. For example, the number of attainment days of Beijing has increased from 100 in 1998 to 286 in 2012. However, this increase is different from residents' feeling because people in Beijing endured several serious fog-haze events in the winter of 2012, which suggests that there is no great improvement but rather some deterioration in the atmospheric environment according to people's sensing. This inconsistency in the public perception that air quality is still worse considering the frequent haze-fog events and environmental data has forced the Ministry of Environmental Protection of China to release a new national ambient air quality standard (NAAQS-2012) (You, 2014).

In the NAAQS-2012, PM2.5, ozone and carbon monoxide concentrations are included in the monitoring of urban ambient air quality in addition to PM10, sulfur dioxide, and nitrogen dioxide concentrations (You, 2014). Additionally, hourly real-time web reporting to the public is requested in addition to daily reporting in the NAAQS-2012 compared to the NAAQS-1996. Under this standard, 72 major cities (mainly the capital, province capitals and economically important cities) are requested to monitor the local ambient air quality with new national standard and to publicize the air quality data in both the local web platform and the national platform of the Ministry of Environmental Protection (http://113.108.142.147:20035/emcpublish/) beginning in January 2013. Beginning in 2014, up to 190 cities have publicized their local ambient air quality under new national standards in the national platform. Since January 2013, API under the NAAQS-1996 has been replaced by a new index called air quality index (AQI) and has not been reported since then.

The inclusion of PM2.5, ozone and carbon monoxide concentrations, especially the PM2.5 concentration, in the air quality standard will no doubt pose great pressure on the local government as the new standard brings stricter requests for the ambient air quality. This pressure will increase the difficulty for local governments to attain the standard. However, a statistical comparison between the two versions of the NAAQS is lacking as the air monitoring data before 2013 are not sufficient to calculate the AQI, and API data are not publicized after 2013. Another difficulty is that, although the real-time AQI data are publicized in the web platform, historical data are not available for researchers to download. This difficulty has prevented researchers from comparing the results of the NAAQS-1996 and NAAQS-2012 and analyzing the long-term pollution situations of major urban areas.

With the help of non-government web platforms (http://www.pm25.in/, http://aqicn.org/) and the national web platform, we are able to download real-time data from January 2013 in a web server at 1-h intervals. In total, historical data from January 18, 2013, to April 3, 2014, of all of the monitoring stations in mainland China have been collected. Approximately 5% of the data are missing due to net breakdown or transfer problems. To provide a comparison between the two versions of the NAAQS, we calculated the daily AQI and API for all of the cities with air monitoring data with two versions of the NAAQS to determine the number of attainment days for the city and national levels. The average annual PM2.5 and PM10 concentrations are also calculated to provide further suggestions for air improvement decisions.

This study provides an evaluation of the national air qualities for major cities under two versions of the NAAQS to present the effects of the new NAAQS on the local air quality assessment compared to the previous NAAQS. Without a doubt, the new NAAQS would decrease the air quality level, but the extent of this decrease will be discussed in this paper for air quality reporting and management. The spatial air quality and air pollution distribution nationwide is also presented and analyzed in this study to understand the present air quality level for China's major cities. The paper is structured as follows. Descriptions of the two versions of the NAAQS are introduced in Section II. Section III describes the attainment level for the city and national levels under two versions of the NAAQS and provides a discussion. Conclusions are given in Section IV.

2. Data and method

2.1. Data

Hourly air quality monitoring data, including PM2.5, PM10, SO_2, NO_2, O_3 and CO concentrations, from January 18, 2013, to April 30, 2014, for 943 fixed monitoring sites in 190 cities were obtained from the national real-time air quality system of China. These data were collected beginning when these stations started to publish air pollutant concentrations and covered a total of more than 6,833,579 site-hour records. Some data were missing due to equipment failure or internet transfer error. Furthermore, some data were problematic due to anomalous measurements. The daily average concentration for each pollutant in a city was obtained by averaging all of the monitoring stations' hourly data from 00:00 to 23:00 within a day if there are at least 20 observations for these stations involved. Because the initial time at which AQI began to be publicized for each city is different, there are 72 city datasets beginning in January 2013, 12 city datasets beginning in March or April 2013, 30 city datasets beginning in October 2013, and 76 city datasets beginning in January 2014. In total, 190 city datasets in China mainland were collected in this research. Monitoring data from Hong Kong and Taiwan are not included in this paper. The first 72 cities and the following 12 cities are the capital (Beijing), province capitals (e.g., Guangzhou) or economically important cities (e.g., Tangshan). The distributions of cities with air quality monitoring stations are shown in Fig. 1.

The cities' daily average concentrations of PM2.5, PM10, sulfur dioxide, nitrogen dioxide and carbon monoxide were calculated by averaging everyday hourly data from 00:00 to 23:00 of all of monitoring stations within each city. For ozone, the maximum 1-h concentration and maximum 8-h averaged concentrations are used instead of daily averages according to NAAQS-2012.

2.2. Method

The API (Air Pollution Index) is an index that indicates the pollution level of the atmosphere, ranging from 0 to 500. The higher the API value is, the heavier is the atmospheric pollution. According to NAAQS-1996, PM10, sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) were included into the calculation of the API. The first step in calculating the API is to calculate the IAPI (Individual Air Pollution Index) for each pollutant. The IAPI of each pollutant mentioned above is calculated as follows:

$$IAPI_P = \frac{IAPI_{Hi} - IAPI_{Lo}}{BP_{Hi} - BP_{Lo}}(C_P - BP_{Lo}) + IAPI_{Lo} \quad (1)$$

where $IAPI_P$ is the individual air pollution index for pollutant P(PM10, sulfur dioxide, and nitrogen dioxide), and C_P is daily mean concentration of pollutant P. BP_{Hi} and BP_{Lo} are the nearby high and low values of C_P as shown in Table 1. $IAPI_{Hi}$ and $IAPI_{Lo}$ are the individual air pollution indexes in terms of BP_{Hi} and BP_{Lo} as shown in Table 1. The largest IAPI value is 500, and once the air pollutant's concentration exceeds the highest limit in Table 1, the IAPI will be set to 500. After the calculation of each $IAPI_P$, the API is then calculated by choosing the max $IAPI_P$ as follows: