Atmospheric Environment 174 (2018) 25–42

Contents lists available at ScienceDirect

Atmospheric Environment

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

A joint prevention and control mechanism for air pollution in the Beijing-Tianjin-Hebei region in china based on long-term and massive data mining of pollutant concentration

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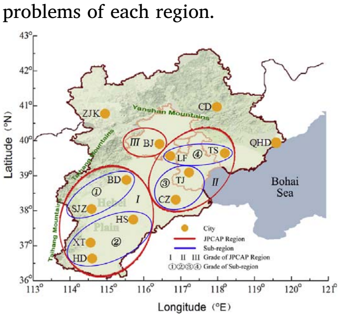
GRAPHICAL ABSTRACT

BJ and the 9 cities i.e. LF, TJ, BD, TS, CZ, HS, SJZ, XT, HD, the latitude of which is lower than that of BJ, are the key cities in JPCAP oriented to the two pollutants in BTH region in China. For JPCAP oriented to $PM_{2.5}$ and PM_{10}, the key JPCAP regions and corresponding pollution control grades are consistent. These results provide a scientific basis for formulating long-term, stable, and unified JPCAP strategies for the BTH region and implementation of JPCAP measures that focus on the specific problems of each region.



ARTICLE INFO

Keywords:
Spatiotemporal distribution
Regional analysis
Pollution control grade
Pollutant concentration data mining

ABSTRACT

China's Beijing-Tianjin-Hebei (BTH) region suffers from the country's worst air pollution. The problem has caused widespread concern both at home and abroad. Based on long-term and massive data mining of $PM_{2.5}$ and PM_{10} concentration, we found that these pollutants showed similar variations in four seasons, but the most severe pollution was in winter. Through cluster analysis of the winter daily average concentration (DAC) of the two pollutants, we defined regions with similar variations in pollutant concentrations in winter. For the most polluted cities in BTH, the relationship between correlation coefficients for winter DAC and the distance between cities revealed that $PM_{2.5}$ has regional, large-scale characteristics, with concentrated outbreaks, whereas PM_{10} has local, small-scale characteristics, with outbreaks at multiple locations. By selecting the key cities with the strongest linear relationship between the pollutant's DAC of each city and the daily individual air quality index values of the BTH region and through cluster analysis on the correlations between the pollutant DACs of the key cities, we defined regional divisions suitable for Joint Prevention and Control of Atmospheric Pollution (JPCAP) program to control $PM_{2.5}$ and PM_{10}. Comprehensively considering the degree of influence of regional atmospheric pollution control (RAPC) on air quality in BTH, as well as the elasticity and urgency of RAPC, we defined the control grades of the JPCAP regions. We found both the regions and corresponding control grades were consistent for $PM_{2.5}$ and PM_{10}. The thinking and methods of atmospheric pollution control we proposed will have broad significance for implementation of RAPC in other regions around the world.

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https://doi.org/10.1016/j.atmosenv.2017.11.027
Received 7 September 2017; Received in revised form 13 November 2017; Accepted 16 November 2017
Available online 21 November 2017

1. Introduction

The update of the urban air quality database by the World Health Organization (WHO) on 12 May 2016 revealed that more than 80% of the world's people who live in urban areas that monitor air pollution were exposed to air quality levels that exceed WHO limits. According to the monitoring data from 2011 to 2015, the five megacities (those with a population of more than 14 million) with the highest particulate matter pollution level were New Delhi, Cairo, Dhaka, Calcutta, and Mumbai. All of these cities are located in developing countries. The situation in the developed world is better, since most countries in Europe and America have already paid a heavy price to control their air pollution. However, weak environmental protection awareness and lower-level environmental initiatives in developing countries mean that, at present, many countries plagued by air pollution lack a scientific mechanism for air pollution control.

In recent years, air pollution has become an increasingly prominent problem in China. This has aroused heated discussion both at home and abroad. Air pollution in China has distinct regional characteristics. For example, the Beijing-Tianjin-Hebei (BTH) region has some of the most severe air pollution in China, and exhibits repeated outbreaks of fog and haze. Particulate-matter pollution in the 2.5- and 10-μm categories ($PM_{2.5}$ and PM_{10}, respectively) has become a major component of the pollution problem in the BTH region (Wang and Hao, 2012). Because the air pollution status in a city depends not only on itself, but also on other cities surrounding it, Joint Prevention and Control of Atmospheric Pollution (JPCAP) is an effective way to improve regional air quality. As early as May 2010, the Ministry of Environmental Protection (MEP) of the People's Republic of China, together with eight other ministries, proposed guidelines for promoting the control of multiple pollutants and regional air pollution (MEP, 2010). This was the first comprehensive policy document that aimed to improve regional and urban air quality in China. This document designated the BTH region as one of three key regions in which to implement JPCAP, and proposed to establish a unified mechanism for planning, monitoring, supervision, evaluation, and coordination of the regional JPCAP. In September 2013, a regional JPCAP mechanism was established to promote synergy of pollution management in the BTH region and to implement 10 measures determined at an executive meeting of the State Council in June 2013.

To address the air pollution problem in the BTH region, China's government has formulated a series of programs and measures. MEP and other departments jointly issued the document on detailed rule for the implementation of air pollution prevention and control action plan in the BTH region and the surrounding areas. Many heavily polluting enterprises were eliminated and the coal-fired units in Takai thermal power plants were fully shut down. Driving restrictions were implemented and a lot of vehicles that did not meet current pollutant emission standards were eliminated. Despite these efforts, the annual MEP ranking of the 10 worst cities for air quality included 7 cities in the BTH region in 2013 (MEP, 2014), 8 in 2014 (MEP, 2015), and 7 in 2015 (MEP, 2016). Thus, achieving success for JPCAP in the BTH region will be a long-term process and air pollution control will remain a severe challenge (Hao et al., 2007). Clarifying how to carry out JPCAP in the BTH region has become the top priority of environmental coordination development in the region.

The atmosphere is a very complicated system. In BTH, the $PM_{2.5}$ and PM_{10} pollution status were affected by several key factors, such as local emissions of both primary particles and gaseous precursors, regional transport of particles and gaseous precursors, topography and meteorology. The deep research on the correlation among air pollution in the cities should be carried out and the cities should be divided into different JPCAP region according to the correlation characteristics. On this account, firstly, the division of JPCAP region cannot be simply based on administrative region division or short-term pollutant concentration data. It should be based on long-term pollutant concentration data and from the perspective of the correlation of pollutant concentration between cities. Secondly, the pollution status, the industrial status and the urban development level etc, in the regions are different. In addition, pollution control requires great financial support. There should be priority in the implementation of pollution control in the JPCAP regions to ensure the JPCAP program is targeted. Therefore, identifying the key JPCAP regions within the BTH region and the corresponding pollution control grades will be a crucial step for formulating long-term policy on JPCAP and implementing JPCAP effectively. Without grasping the core issues, the air pollution in BTH can not be fundamentally solved.

Recently, many researchers have concentrated on air pollution levels during specific periods (Wang et al., 2014) or in specific regions and some representative cities of those regions (Han et al., 2010; Huang et al., 2014; Liu et al., 2013; Wang et al., 2016). Some researchers have focused on the formation of air pollution (Feng et al., 2012; Pathak et al., 2009), its development (Peng et al., 2016), and its apportionment among sources (Hua et al., 2015; Wang et al., 2015). Others have analyzed regional spatial and temporal variations of air pollution (Chow et al., 1994; Gomiscek et al., 2004; Hu et al., 2014). These researches are mostly focused on short-term pollution status, not based on long-term and massive pollutant concentration data. Although some have studied mechanisms for regional atmospheric pollution control (RAPC) in specific cities from a micro-scale perspective (Zhang et al., 2016) and theoretical and methodological aspects of JPCAP from a macroscopic perspective (Wang et al., 2012), the division of JPCAP region was only based on economic or social analyses, or only air basin theory. Many researchers have focused on the regional air pollution control (Bergin et al., 2005; Castells and Ravetz, 2001) and the cost-effectiveness of JPCAP (Wu et al., 2015). Owing to the diverse conditions under which the pollution forms and the diverse opportunities for its spread, as well as differences in the national conditions (e.g., stage of economic development, climate) that affect the pollution, little research (e.g., Nordenstam et al., 1998) presently exists on mechanisms to optimize JPCAP, especially from the perspective of combining control at key local sources with regional joint prevention and control.

In practice, owing to a lack of institutional arrangements, clear ideas, and scientific evidence, few long-term JPCAP practices are currently being used in China and other countries around the world. Our current research started with an analysis (Wang et al., 2016) of the spatiotemporal distributions of pollutants. In the present study, we used long-term tracking data, government summaries, and data mining to obtain $PM_{2.5}$ and PM_{10} concentration data that let us analyze the status of these pollutant categories in the BTH region and explore potential mechanisms to implement JPCAP focused on $PM_{2.5}$ and PM_{10}. In addition, because air quality index (AQI) is the primary metric of air quality and at the same pollutant concentration level, the influence of $PM_{2.5}$ on air quality is greater than that of PM_{10} (Table 1), individual air quality index (IAQI) as standardized metric of air quality oriented to different pollutants was used in this study. Here, we used the method for calculating IAQI values from the Technical Regulation on Ambient Air Quality Index (HJ 633–2012) issued by MEP in 2012 (http://kjs.mep.gov.cn/hjbhbz/bzwb/dqhjbh/jcgfffbz/201203/

Table 1
Pollutant concentration limits corresponding to the individual air quality index (*IAQI*) values.

IAQI	$PM_{2.5}$ (μg/m^3)	PM_{10} (μg/m^3)
0	0	0
50	35	50
100	75	150
150	115	250
200	150	350
300	250	420
400	350	500
500	500	600