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Effectiveness evaluation of temporary emission control action in 2016 in winter in Shijiazhuang, China

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The measurement of the height of mixed layer

The height of mixed layer was measured at an atmospheric gradient monitoring station of Shijiazhuang with a lidar scanner (AGHJ-I-LIDAR (HPL), Zhongke Guangdian, Wuxi, China). The lidar scanner use 532 nm linearly polarized laser to accomplish the remote sensing detection of atmospheric particulate matters. Based on the vertical and horizontal polarization signal detection, the lidar can analyze some parameters about atmospheric layer, including atmospheric extinction coefficient, polarization ratio profile, height and optical thickness of mixed layer and so on. And then, information about temporal and spatial distribution-characteristics of atmospheric particulates, the spatial and temporal variations of atmospheric pollution layer, the transmission and deposition of particulate pollution can be obtained.

Control measures during the TECA period

(1) **Reduce the usage of coal.** The generating capacity of thermal power enterprises is reduced to the utmost. Coal-fired facilities without using clean fuels are shut down, whose steaming tons are less than 20 tons and don't undertake the task of centralized heating. The non-civilian coal-fired facilities in gas-related enterprises have to be shut down.

(2) **Decrease industrial production.** Except for the enterprises that provide residential heating and ensure people's livelihood, all the industrial enterprises in the whole city which include steel, cement, coke, casting, glass, ceramics, etc. are obliged to stop production. In principle, all the production processes that can generate volatile organic compounds (VOCs) are shut down. All the gas-related enterprises that cannot meet the standard emissions must stop production.

(3) **Inhibition of dust emission.** The main urban areas of Shijiazhuang and built-up areas of county are prohibited from the building demolition, road excavation, concrete mixing and earthwork, etc. without the approval of the municipal government. All building sites are used in totally-enclosed dustproof measures. All the open-air mines, sand mining, stone processing, and sand and stone processing industry must stop production in the whole city.

(4) **Driving restriction**. Motor vehicles are restricted on the basis of odd-and-even license plate rule in urban area of Shijiazhuang, and the bus-travel is free during the sword action period. Strictly prohibited the sale of gasoline, diesel and ordinary diesel oils that don't meet the fifth stage vehicle emission standard in China

(http://www.zhb.gov.cn/gkml/hbb/bgg/201601/t20160118_326596.htm, last access: 12 July 2017). The system of staggered working hours is implemented in all the administrative departments and institutions in the whole city.

(5) **Prohibit open burning**. Crack down on these behaviors that burning straw, garbage, leaves, weeds, and burning mountain, etc. in the whole city during the control action period.

Data calculation and quality control

In this paper, the monitoring sites of air quality distributed throughout the city of Shijiazhuang (Fig. 1), which caused to the concentrations of air pollutants have large spatial-differences. In addition, Shijiazhuang city experienced several heavy pollution processes during the temporary emission control action (TECA) period (Fig. 2), likely leading to the concentrations of air pollutants have larger temporal-differences. Therefore, the error bars are large in this study (as shown in Fig. 3). For the same reasons, the error bars of the chemical species in $PM_{2.5}$ are also larger (Figs. 6 and 7).

The monitoring sites belonged to national, provincial and city controlling points (as shown in Sect. 2.2.1 in paper), and all of them are managed in a standardized way. They all have quality assurance and quality control (QA/QC) system. In addition, there is a strict quality control for the collection and analysis of the ambient $PM_{2.5}$. Therefore, the quality of the data itself is guaranteed in this study.

Here, the decreased or increased values for the air pollutants or chemical species concentrations during different control stages were calculated at each monitoring sites, and the final results were obtained from the average values of these sites, so that the uncertainty of results can be further reduced in this paper.

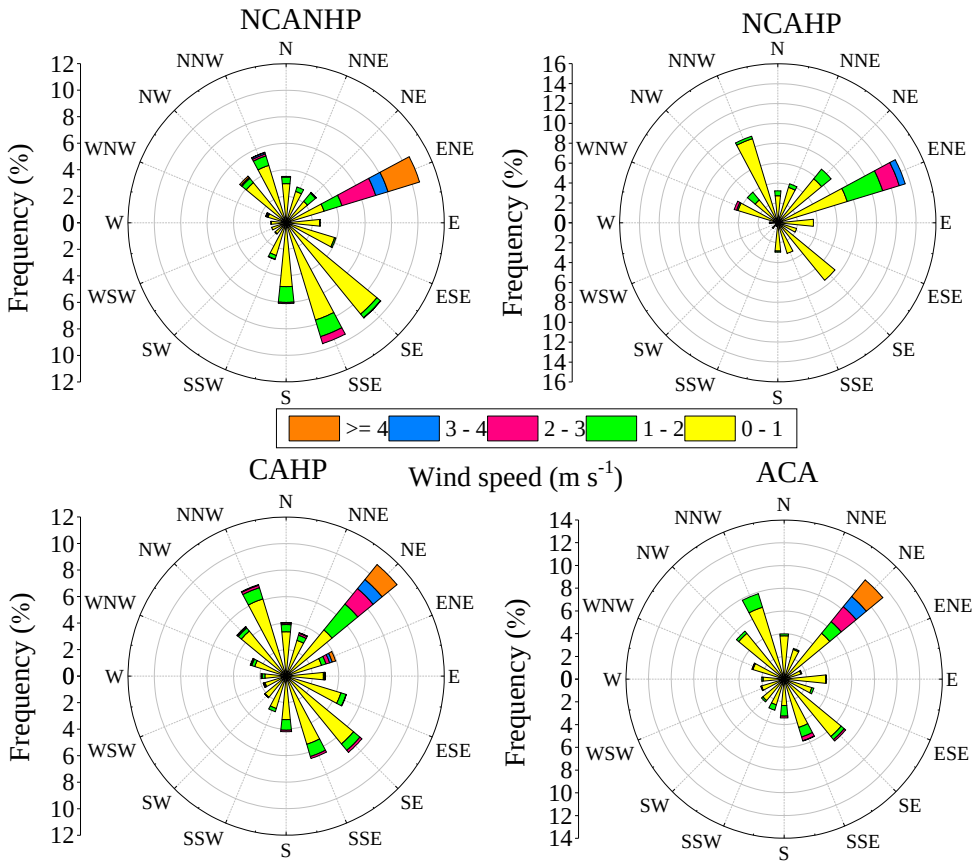

Figure S1. Rose map of wind directions and wind speeds in Shijiazhuang during the four stages of TECA period.

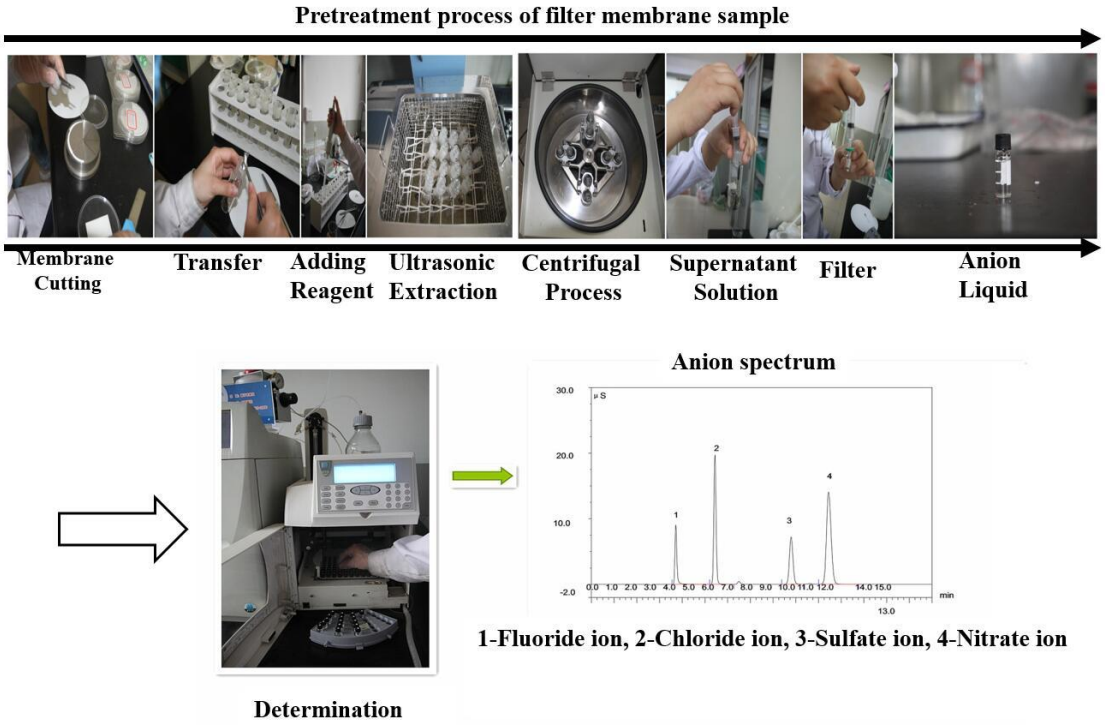

Figure S2. The determination process of anions in the $PM_{2.5}$ filter membrane samples.

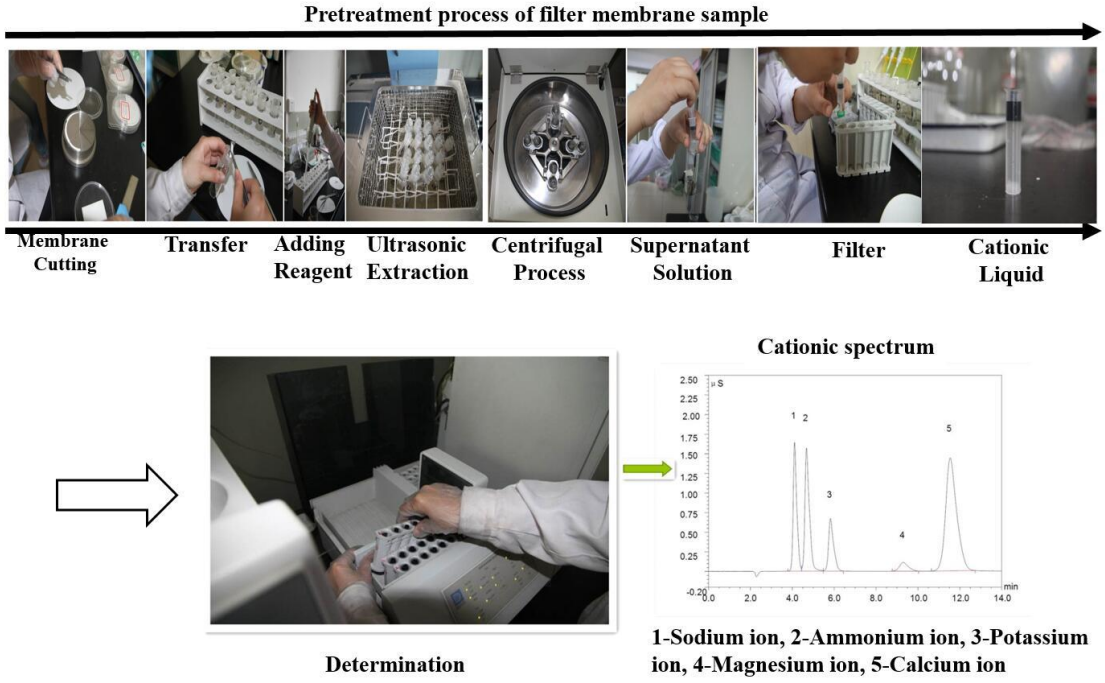

Figure S3. The determination process of cations in the $PM_{2.5}$ filter membrane samples.

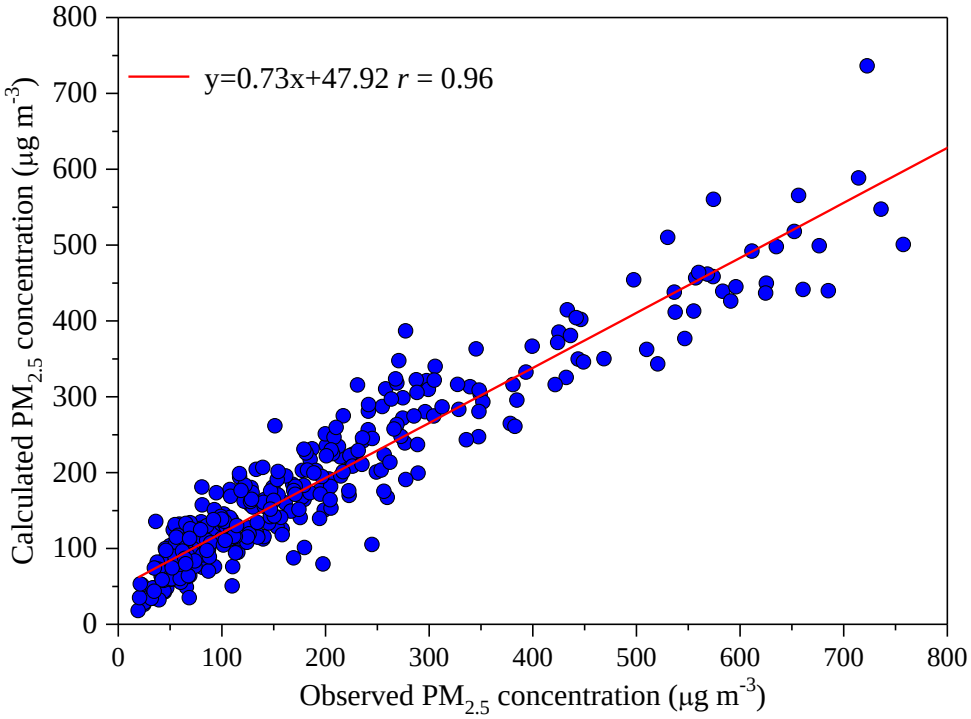

Figure S4. Correlation between observed and calculated $PM_{2.5}$ concentrations during the whole sampling period: November 24, 2015 to January 9, 2017. Also shown is the linear regression line with regression equation.

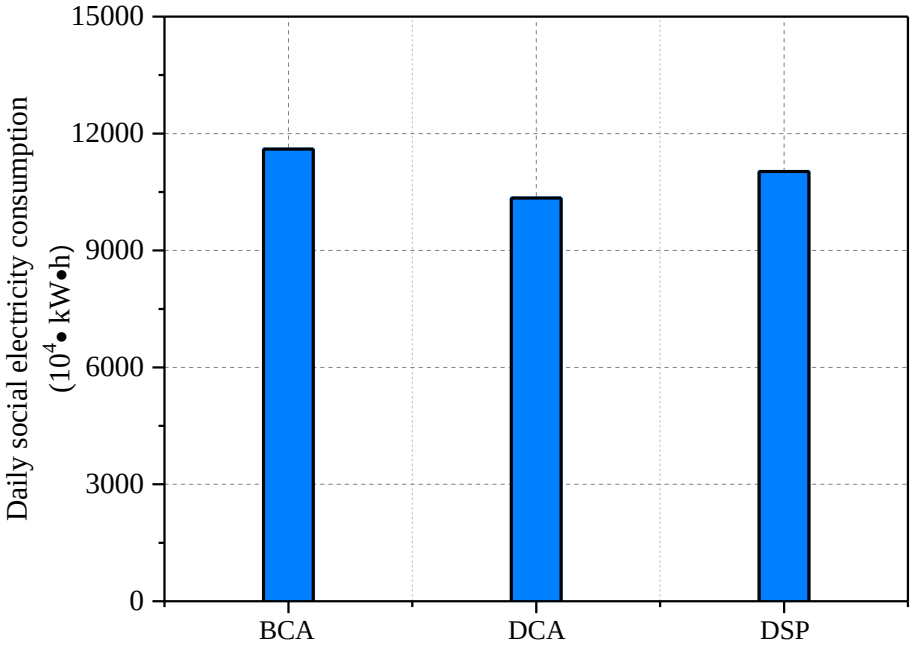

Figure S5. Daily social electricity consumption during the TECA period in Shijiazhuang. BCA represents before the control action i.e. from November 1 to 17, 2016; DCA represents during the control action i.e. November 18 to December 31, 2016; DSP represents during the same period of the TECA in 2015 i.e. November 18 to December 31, 2015.

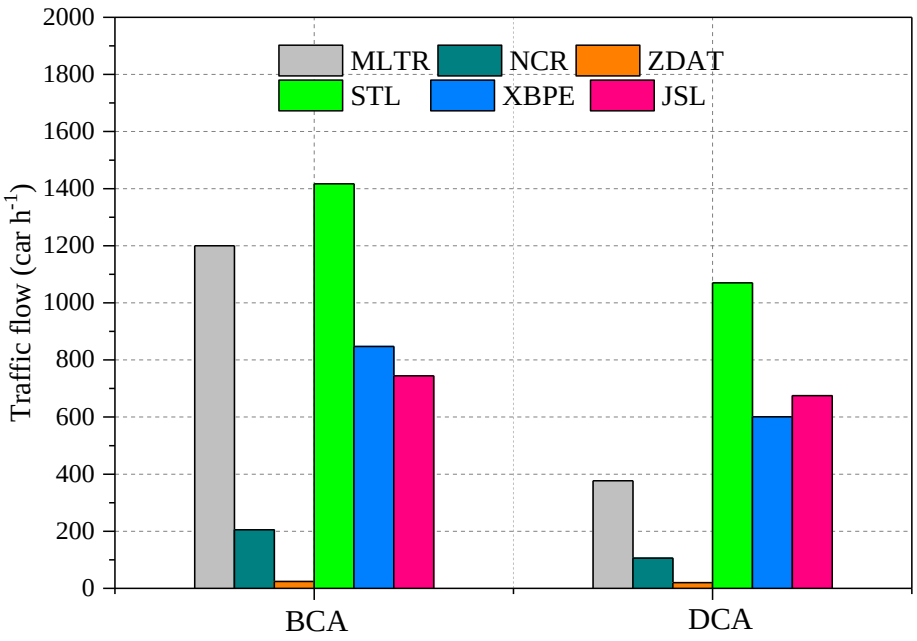

Figure S6. The average traffic flow on arterial roads during different stages of TECA. BCA represents before the control action i.e. from November 1 to 17, 2016; DCA represents during the control action i.e. November 18 to December 31, 2016. The arterial roads include the main line of the third ring road (MLTR), new city road (NCR), the road that from Zhengding high-speed railway station to airport (ZDAT), the Shitai line of Beijing-Kunming expressway (STL), Xibaipo expressway (XBPE) and Jingshi line of the Beijing-Kunming expressway (JSL).

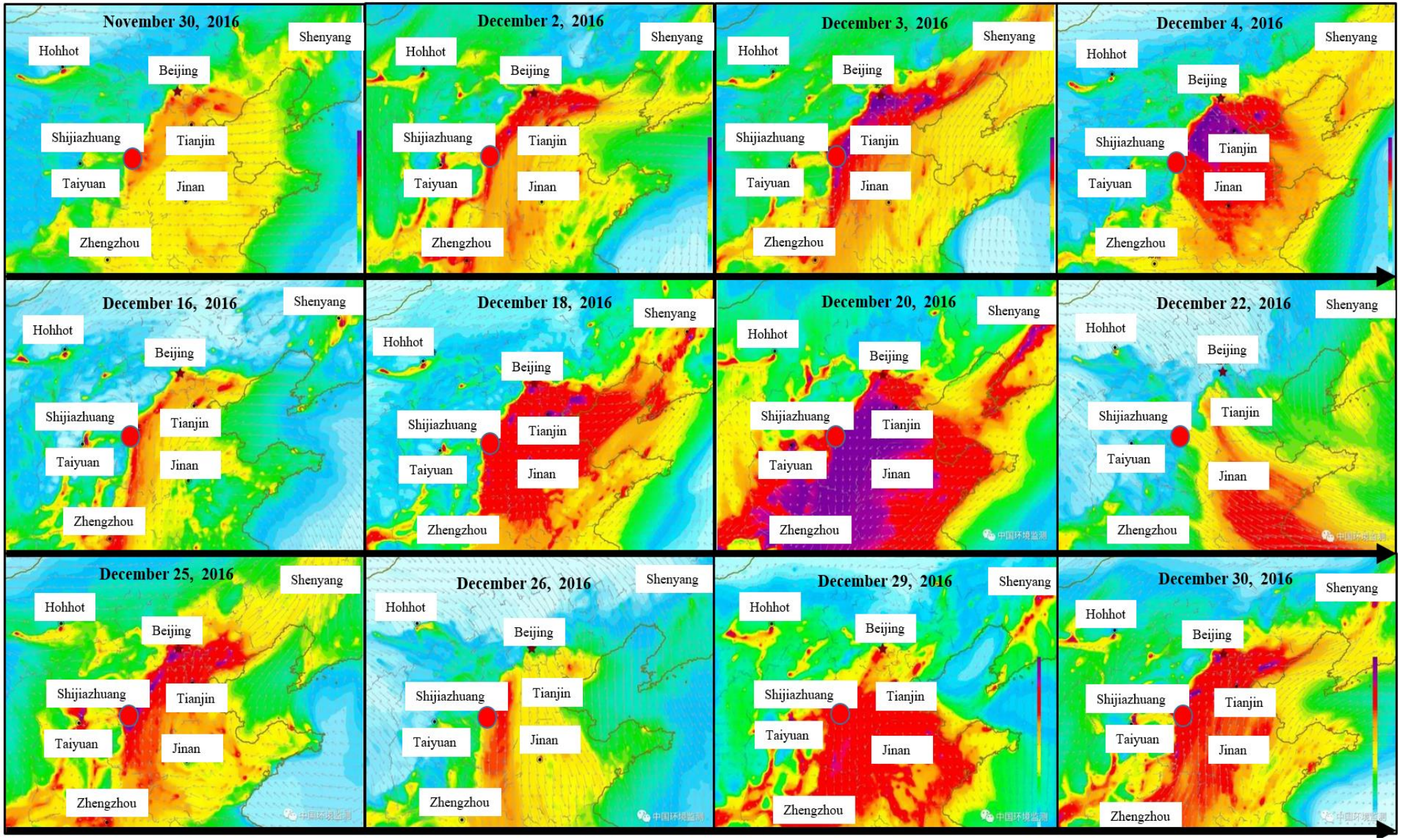

Figure S7. The meteorological flow field maps and the spatial distributions of $PM_{2.5}$ in Shijiazhuang during the CAHP. Red and violet represent high $PM_{2.5}$ concentration areas. The arrows represent the movement direction of the air masses. Pictures are cited from the website of the China Environmental Monitoring Station (http://www.cnemc.cn/).

Table S1. Details of the twenty-four monitoring sites in Shijiazhuang during the TECA period.

Full Names of Monitoring Sites	Abbreviations	Areas	Cities/Counties	Longitude (°)	Latitude (°)
The 22nd middle school	TSMS	Urban	Shijiazhuang City	114.56	38.04
High-tech zone	HTZ	Urban	Shijiazhuang City	114.60	38.04
Great Hall of the People	GHP	Urban	Shijiazhuang City	114.52	38.05
Century Park	CP	Urban	Shijiazhuang City	114.54	38.03
Water source area in the northwest	WSAN	Urban	Shijiazhuang City	114.50	38.14
University area in the southwest	UAS	Urban	Shijiazhuang City	114.47	38.01
Staff hospital	SH	Urban	Shijiazhuang City	114.45	38.05
Fenglong Mountain	FLM	Suburb	Suburb of Shijiazhuang	114.35	37.91
Gaoyi	GY	Suburb	Gaoyi County	114.61	37.62
Gaocheng	GC	Suburb	A district, Shijiazhuang	114.86	38.04
Xingtang	XT	Suburb	Xingtang County	114.56	38.44
Jinzhou	JZ	Suburb	Jinzhou City	115.08	38.04
Jingxing mining district	JXMD	Suburb	Jingxing County	114.07	38.07
Lingshou	LS	Suburb	Lingshou County	114.37	38.31
Luquan	LQ	Suburb	A district, Shijiazhuang	114.35	38.08
Luancheng	LC	Suburb	A district, Shijiazhuang	114.63	37.91
Pingshan	PS	Suburb	Pingshan County	114.20	38.27
Shenze	SZ	Suburb	Shenze County	115.21	38.20
Wuji	WJ	Suburb	Wuji County	114.99	38.18
Xinle	XL	Suburb	Xinle City	114.69	38.35
Yuanshi	YS	Suburb	Yuanshi County	114.52	37.77
Zanhuang	ZH	Suburb	Zanhuang County	114.39	37.67
Zhaoxian	ZX	Suburb	Zhaoxian County	114.77	37.77
Zhengding	ZD	Suburb	Zhengding County	114.59	38.16

Table S2. Detailed information on the online sampling.

Items	Production company	Model number
SO_2	Teledyne-API, America	T100
NO_2	Teledyne-API, America	T200
CO	Teledyne-API, America	T300
O_3	Teledyne-API, America	T400
$PM_{2.5}$ and PM_{10}	XianHe, Hebei, China	XHPM2000E
Meteorological parameters	Davis, America	Vantage Pro2

Table S3. Details of the filter membrane sampling in Shijiazhuang.

Sampling Sites	Sampling period	Sample number	Sampling Instrument	Flow Rate	Sampling Period	Filter Diameter	Filter Pore Size
LC[a]	20151124-20170109	260	Thermo Scientific Partisol 2025i	16.7L min^{-1}	23h	47mm	1μm
LQ[b]	20151124-20170109	260	Thermo Scientific Partisol 2025i	16.7L min^{-1}	23h	47mm	1μm
TSMS[c]	20151124-20170109	260	Thermo Scientific Partisol 2025i	16.7L min^{-1}	23h	47mm	1μm

[a]LC represents Luancheng site, [b]LQ represents Luquan site, [c]TSMS represents the 22nd middle school site.

Table S4. The detection limits of all the elements by ICP-MS[a].

Elements	Detection limits (μg m^{-3})	Recovery rate (%)
Al	2.1×10^{-2}	82
Si	1.7×10^{-2}	83
Ti	1.4×10^{-3}	86
Cr	6.8×10^{-4}	100
Mn	6.4×10^{-4}	88
Fe	2.2×10^{-2}	86
Cu	1.4×10^{-2}	94
Zn	3.7×10^{-2}	120
As	6.5×10^{-5}	87
Pb	1.0×10^{-2}	90

[a] ICP-MS represents inductively coupled plasma–mass spectrometry

Table S5. The numbers of closed specific-enterprises in different districts and counties of Shijiazhuang during the TECA period.

Districts and Counties	Number	Districts and Counties	Number
High-tech District	15	Pingshan County	59
Gaoyi County	26	Qiaoxi District	3
Gaocheng district	50	Shenze County	4
Xingtang County	23	Wuji County	13
Chemical Industry Park	5	Xinhua District	14
Jinzhou City	115	Xinle City	61
Jingxing Mining District	11	Yuhua District	1
Jingxing County	121	Yuanshi County	12
Lingshou County	559	Zanhuang County	16
Luquan District	121	Changan District	201
Luancheng District	69	Zhengding County	44