Analysis on the causes of air pollution during the Spring Festival in Xi'an and the effectiveness of the government's ban on fireworks

Su Jing 1, Lin Yang 2, Cao Hongli 3, Meng Zhen 1, Li Wei 1, Hu Jinyi 1

1Shaanxi Provincial Atmospheric Sounding Technical Support Center, Xi’an 710014, Shaanxi, China;
2Meteorological Institute of Shaanxi Province, Xi’an, 710016, China.
3Xi’an City Meteorological Bureau, Xi’an 710015, Shaanxi, China

Corresponding authors: hlinbb@126.com (Su Jing), li2010lily@163.com (Lin Yang), c15929558669@163.com (Cao Hongli)

Abstract: This paper analyzed the air pollution in view of the increasingly serious air pollution in Xi'an, this paper analyzes the air pollution in Xi'an, focused on the effects of pollution source emission and meteorological conditions on ambient air quality. The results showed that the concentration of particulate matter decreased significantly during the Spring Festival with the increase of the ban on fireworks. In addition this paper combined with the public survey, discussed the necessity of banning fireworks and firecrackers, in order to provide ideas for the government to take feasible control measures in the work of pollution prevention and haze control.

1. Introduction
As the capital and vice provincial city of Shaanxi Province, Xi'an is an important central city in Western China approved by the State Council, as well as an important national scientific research, education and industrial base. Xi'an formerly known as Chang'an and Hao’jing, it is one of the four ancient capitals in China, a world famous historical city determined by UNESCO in 1981, it is one of the top ten ancient capitals in the world selected by American media[1-4]. Guanzhong urban agglomeration with Xi'an as the center is located in Guanzhong Basin. In winter, environmental air pollution occurs frequently, and it often happened at the same time with Beijing Tianjin Hebei Zhengzhou, the ecological environment is fragile and worse[5-6]. Especially during the Spring Festival, air pollution is more prominent, which has caused widespread concern from all walks of life. Air pollution has become the most prominent environmental problem in Xi'an and even Guanzhong[7-8]. Therefore, Xi'an municipal government has issued a series of control measures, such as comprehensive control of dust, prohibition of straw burning, prohibition of fireworks burning and control of volatile organic compounds, unswervingly implement all tasks of air pollution control. Based on the comparative analysis of air quality data and corresponding meteorological data in Xi'an, this paper referenced the policy documents issued by Xi'an municipal government on banning the setting off of fireworks and firecrackers, analyzed the current situation of ambient air quality in Xi'an and the influence of pollutant emission and meteorological conditions on air quality, focused on the changes of air quality during the Spring Festival in recent years, discussed the environmental impact of the government's ban on fireworks and firecrackers and the necessity of the ban.
2. Data and Methods
This paper selected the daily and hourly pollutant concentration data and AQI index data of 13 national monitoring stations in Xi'an from 2013 to 2018, the surface meteorological elements data such as wind speed of the national benchmark station—Jinghe station and atmospheric circulation characteristics. The meteorological data used in the study are from Shaanxi meteorological information center, and the pollutant concentration data are from the national environmental monitoring station. The data are accurate and reliable after strict quality control and inspection.

3. Air Quality

3.1. Ambient air quality grade
Air pollution is phenomenon caused by human activities or natural processes, some substances enter the atmosphere, showing enough concentration, reaching enough time, and thus endangering human comfort, health and welfare or the environment. The quality of ambient air reflects the degree of air pollution, it is judged by the concentration of pollutants in the air. In China, air quality index (AQI)\(^9\) is used to evaluate air quality. The main pollutants involved in air quality assessment are PM\(_{2.5}\), PM\(_{10}\), SO\(_2\), NO\(_2\), O\(_3\) and CO. According to the technical regulations on ambient air quality index (AQI) (Trial) (HJ 633-2012), the following measures are adopted: The value range of air pollution index is 0-500, in which 0-50 means that the air quality is excellent, 51-100 means that the air quality is good, 101-150 means that the air quality is light pollution, 150-200 means that the air quality is moderate pollution, 200-300 means that the air quality is heavy pollution, and more than 300 means that the air quality is serious pollution.

3.2. Air quality since 2013
Through visiting the city's environmental monitoring station and online data collection, we collected the changes of Xi'an's ambient air quality from 2013 to 2019 (Table 1), and monitored and evaluated Xi'an's urban ambient air quality according to the ambient air quality standard (gb3095-2012)\(^{10}\). It can be seen that: in recent years, the average number of good days of ambient air quality in Xi'an is 193 days, and the good rate is only 53%, of which the worst is about 37.8% in 2013. In recent years, particulate matter has been the primary pollutant of ambient air pollution in Xi'an.

Table 1. Classification statistics of ambient air quality in Xi'an from 2013 to 2018 (d)

| Population level         | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|--------------------------|------|------|------|------|------|------|
| excellent                | 9    | 18   | 15   | 17   | 16   | 21   |
| good                     | 129  | 193  | 236  | 175  | 164  | 167  |
| slight pollution         | 106  | 88   | 76   | 97   | 110  | 115  |
| moderate pollution       | 54   | 28   | 19   | 41   | 36   | 33   |
| severe pollution         | 33   | 32   | 18   | 29   | 24   | 24   |
| serious pollution        | 34   | 6    | 1    | 7    | 15   | 5    |
| excellent and good days  | 138  | 211  | 251  | 192  | 180  | 188  |
| proportion of excellent and good days | 37.8 | 57.8 | 68.8 | 52.6 | 49.3 | 51.5 |
From Figure 1 and Figure 2 we can see: In recent years, the ambient air quality from good to bad is 2015, 2014, 2016, 2018, 2017 and 2013, the best rate of air quality was less than 40% in 2013. In recent years, the ambient air quality has improved, the number of excellent days is increasing slowly, the excellent and good rate is more than 50%.

### 3.3. Ambient air quality during Spring Festival and in winter

By analyzing the monthly concentration of pollutants and the days of moderate or above pollution, it can be found that (Table 2 and Figure 3): The changes of AQI index and particulate matter concentration can be divided into winter half year and summer half year. The order of monthly average concentration was as follows: January, December, February, November, March, April, October, May, August, September, June and July, the concentrations of particulate matter from January to March and from November to December were higher than the annual average. During the year, the concentration of particulate matter and the number of pollution days changed in a V-shaped pattern with seasons, reaching the peak in January and December in winter.

**Table 2. Monthly particulate matter concentration in Xi’an from 2013 to 2018 (ug/m³)**

| month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| concentration | 216 | 172 | 154 | 125 | 113 | 79  | 74  | 81  | 80  | 117 | 164 | 195 |

As can be seen from Figure 4: In winter, the monthly pollution rate exceeded 60%, and it was more than 70% in January and December, the moderate pollution rate exceeded 50% in January. The main reason may be the increase of pollutant emission in winter heating period and the adverse weather conditions such as low wind speed and strong inversion in winter.

### 4. Causes of Air Pollution

#### 4.1. Terrain

Xi’an is located in the hinterland of the mainland and the Guanzhong Basin of the Yellow River Basin. It is between 107.40° E-109.49° E and 33.42° N-34.45° N. The altitude is only about 400 meters. But,
in the north is the Loess Plateau with an altitude of 800-3000 meters, in the south, it is adjacent to the Qinling Mountains with an altitude of 2000-2800 meters, in the west, it is bounded by Taibai Mountains and Qinghua loess tableland. The special dustpan shaped terrain limits the diffusion and transmission of aerosols in the whole Guanzhong area, the atmosphere over Xi’an is mostly stable, It is easy to form pollution accumulation, become a large area of pollution gathering place. Thus, affected by the terrain, Xi'an has become one of the most difficult cities in China to reach the standard.

4.2. Wind

The relationship between ambient air quality and meteorological conditions is very close. Li Ganjie, Minister of the Ministry of ecological environment, said that the impact of atmospheric conditions on the air in general cities is plus or minus 10%, that is to say, the emission and other factors remain.

As shown in Figure 5: The maximum wind direction in Xi'an is northeast, and the annual wind speed is small, the frequency of static wind is high, temperature inversion occurred frequently and lasted for a long time, these are not conducive to the diffusion of pollutants near the ground, easy to form pollutant accumulation and cause environmental air pollution. The maximum wind direction in Xi'an is northeast wind. The probability of pollution weather in Xi'an is the highest under the condition of calm wind. There are the highest probability of pollution in autumn and winter, the pollution weather in Xi'an all year round and four seasons mostly occurs in the East and northeast wind direction.

In general, low wind speed, more static wind, and northeast wind is prevalent are not conducive to pollutant diffusion.

By analyzing the distribution of wind speed in polluted days, we can find that (Table 3): In 2013-2018, the average daily wind speed was less than or equal to 1.5 m/s, and there were 277d pollution days, accounting for 30% of the total times; The wind speed in 1.5-3.0 m/s appeared 495 days, accounting for 54%, Wind speed ≥ 3 m/s only occurred in 153d, accounting for about 16%. It can be seen that when the near surface wind speed is less than 3.0 m / s, the horizontal and vertical diffusion ability of the atmosphere is relatively low, and it is easy to form pollution weather. When the near surface wind speed is greater than or equal to 2.0 M / s, the probability of pollution weather is significantly reduced.

| Wind speed (m/s) | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | proportion (%) |
|------------------|------|------|------|------|------|------|----------------|
| ≤1.5             | 61   | 26   | 36   | 37   | 46   | 50   | 22.8           |
| 1.5~3            | 112  | 109  | 56   | 107  | 11   | 77   | 41.9           |
| ≥3               | 48   | 24   | 12   | 22   | 22   | 25   | 18             |

Compared and analyzed the monthly distribution of pollution days in 2013-2018. There are more pollution days in from January to March and from October to December. Severe pollution mainly occurred in three months of winter. In more depth, analyzed the meteorological factors above pollution and heavy pollution in January, February and December in winter (Table 4) - It was found that the average daily wind speed of Xi'an city was 1.9m/s in the weather above moderate pollution, wind speed
of heavy pollution is 1.6m/s, wind speed of good and excellent weather in Xi'an is 2.4m/s. There are obvious differences in average wind speed among severe polluted weather, polluted weather and fine weather. The average wind speed is the lowest in severe pollution weather, is high in good and excellent weather. The daily average wind speed in severe pollution weather is about 33% lower than that in good and excellent weather.

Table 4. Meteorological factors of different air quality level

| Air quality level       | Wind speed(m/s) |
|-------------------------|-----------------|
|                         | Jan  | Feb  | Dec  | average |
| Above moderate pollution| 1.6  | 1.9  | 1.5  | 1.6     |
| pollution               | 1.9  | 2.0  | 1.8  | 1.9     |
| good and excellent      | 2.5  | 2.5  | 2.2  | 2.4     |

4.3. Pollution sources

Pollutant emission is the main and internal cause of heavy air pollution\(^{11-15}\), high emission intensity is the main cause of heavy air pollution in autumn and winter in Xi'an and its surrounding areas. Setting off fireworks and firecrackers in the Spring Festival is a folk custom in China for thousands of years. The sound of firecrackers brings a festive atmosphere to the new year. As an old saying goes, "firecrackers say goodbye to the old year". People send off the past year with the sound of firecrackers. However, while adding to the festive atmosphere, fireworks and firecrackers bring serious air pollution. Smoke is diffuse, the concentration of particulate matter seriously exceeds the standard, which is harmful to people's health. The analysis of 2013 Spring Festival particulate matter is shown in the figure below.

Figure 6 is the hourly variation of particulate matter concentration during the Spring Festival in 2013. It can be seen that: During the Spring Festival, the primary pollutant in Xi'an is inhalable particulate matter. From New Year's Eve to the first day of the lunar new year, there are large-scale and phased fireworks in Xi'an, and the air pollutants increase rapidly, which directly leads to the decline of air quality. Especially at 19:00 on New Year's Eve (February 9), the concentration of particulate matter increased linearly (Figure. 6), from 23:00 on New Year's Eve to 13:00 on the first day of the Lunar New Year (February 10), the monitoring results in Xi'an showed that the air quality was extremely poor (over 600ug/m\(^3\)). On the other hand, the concentration of particulate matter is close to 1000ug/m\(^3\) on the first day of the first lunar month, which is the most concentrated time for firecrackers. Setting off fireworks and firecrackers during the Spring Festival is the most important factor for the serious decline of air quality in Xi'an\(^{17-18}\). So, in order to reduce air pollution and protect people's health, it is imperative to restrict and prohibit fireworks.

Figure 6. Hourly variation curve of particulate matter concentration during the Spring Festival in 2013 (ug/m\(^3\))
4.4. Prohibition of fireworks
In recent years, in order to deal with the increasingly serious environmental air pollution in Xi'an, the government has taken various measures from adjusting the industrial structure, optimizing the urban layout, controlling pollution and other aspects to improve the environmental air quality. Since 1994, Xi'an municipal government has issued five documents or regulations prohibiting the sale of fireworks and firecrackers[18]. In Feb 1994, Xi'an approved the "Xi'an ban on the sale of fireworks regulations". The districts under the jurisdiction of the sub district offices of Xincheng, Beilin, Lianhu, Yanta, Baqiao, Weiyang and Yanliang districts are the districts where the sale of fireworks and firecrackers is prohibited. In 2003, 2007 and 2010, the Standing Committee of the 10th Shaanxi Provincial People's Congress approved three amendments to the decision on Amending the provisions of Xi'an Municipality on banning the sale and setting off of fireworks and firecrackers. On Dec 1, 2017, the regulations on the safety management of fireworks and firecrackers in Xi'an city was officially implemented, it clearly stipulates that: The six districts of the city (Xincheng, Beilin, Lianhu, Yanta, Baqiao and Weiyang) are prohibited from selling and setting off fireworks. During the heavy pollution weather warning and emergency response, fireworks and firecrackers are prohibited in the administrative area of Xi'an. In addition, Lintong, Chang'an, Gaoling, Zhouzhi, Huyi and Lantian have also designated some areas where fireworks can not be set off.

As an important measure of pollutant emission reduction, the level of relevant documents is getting higher and higher. From regulation to law, the discharge of fireworks and firecrackers has been reduced from reducing discharge to banning burning in the Sixth District of the city to designating banning burning areas in the Sixth District of the city and other areas, which has played a significant role in improving the ambient air quality during the Spring Festival.

Table 5. Days of pollution during the Spring Festival in 2013-2018 (d)

| Air quality level | 2013 | 2014 | 2015 | 2016 | 2016 | 2017 | 2018 |
|-------------------|------|------|------|------|------|------|------|
| serious pollution | 2    | 3    | /    | /    | /    | /    | 2    |
| severe pollution  | 1    | 1    | /    | 2    | 2    | 2    | 1    |
| moderate pollution| 1    | 1    | /    | 2    | 1    | 2    | 1    |
| slight pollution  | 2    | 1    | 4    | 1    | 2    | 1    | 2    |
| good              | /    | /    | 2    | 1    | 1    | 1    | /    |
| excellent         | /    | /    | /    | /    | /    | /    | /    |

| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|------|------|------|------|------|------|------|
| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| Year | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |

Figure 7. Particulate concentration during the Spring Festival in 2013-2018

From Table 5 and Figure 7 can be seen: During the six days from New Year's Eve to the fifth day of the lunar new year, in 2013, there were two serious pollution days, one severe pollution day, one moderate pollution day and two mild pollution days, the average concentration of particulate matter was 297ug / m³; in 2014, there were three serious pollution days, one severe pollution day, one mild pollution day and one good weather, the average concentration of particulate matter reached 388ug / m³,
reaching the peak in recent years; in 2015, there were two good weather and four mild pollution days; in 2016, there were two severe pollution days, two moderate pollution days, one mild pollution day and one good weather; in 2017, there were 2 severe pollution days, 1 moderate pollution day, 2 mild pollution day and 1 good weather; in 2018, there were 2 severe and 2 moderate pollution days, 1 mild pollution day and 1 good weather; in 2019, there are two severe pollution days, three mild pollution days and one good weather. The average concentration of particulate matter is 172ug / m³, which is 42% lower than that in 2013 and 56% lower than the peak. It can be seen that in recent years, with the government increasing efforts to ban fireworks, the ambient air quality of Xi'an city continued to improve during the Spring Festival.

5. Conclusion and Discussion

(1) During the Spring Festival, the large-scale and periodic discharge of fireworks and firecrackers leads to the rapid increase of air pollutants, which directly leads to the decline of air quality and is the main factor of air pollution during the Spring Festival.

(2) The terrain and meteorological conditions of Xi'an determine the serious air pollution in winter. The topography of Guanzhong Basin limits the diffusion of pollutants, the average daily wind speed of severe pollution weather in Xi'an is about 33% lower than that of fine weather. Therefore, in winter, low wind speed, more static wind and northeast wind are the accomplices of pollutant accumulation during the Spring Festival.

(3) With the increase of the ban on fireworks and firecrackers, the emission of pollutants during the Spring Festival has been significantly reduced, and the ambient air quality of Xi'an has continued to improve during the Spring Festival, The government's effective regulation is the hero of improving air quality during the Spring Festival.

(4) It is suggested that the government should continue to increase the intensity of banning burning and releasing, and do a good job in the emission reduction of pollution sources. On the basis of the work of banning burning and releasing, the government should increase publicity and guide the public to replace the traditional fireworks with electronic firecrackers during the Spring Festival.

This work was supported by a climate change project (CCSF201938, Study on the assessment technology of the impact of pollutant transportation on the haze of Guanzhong Urban Agglomeration) from the China Meteorological Administration. This thesis was completed based on the support and encouragement of many people. The authors are thankful for the guidance of Professor Li Zhan Bin from the Xi'an University of Technology and Professor Hu Lin from the Shaanxi Climate Center. I would like to thank all the authors for their helpful conversations.

Reference:
[1] Wang Shan, Liao TingTing, Wang Li Li, et al. Atmospheric characteristics of a serious haze episode in Xi'an and the influence of meteorological conditions[J]. Acta Scientiae Circumstantiae, 2015, 35(11): 3452-3462
[2] Lin Qicai, Zhang Zhenwen, Du Lilao, et al. Formation and Variation Trends of Air Pollutants in Xi'an in 2013[J]. Environmental Science and Management, 2014, 39(10): 52-55
[3] Long Yanxia, TAN Zhihai, SUN Bin, et al. Current condition and causes of air pollution in Shaanxi province[J]. Journal of X'an Polytechnic University, 2016, 30(1): 43-46
[4] Hong Chao. Characteristics of Air Pollution in Xi'an and Reasons of Heavy Pollution Weather[D], Lanzhou, Lanzhou University, 2017
[5] Huang Shaoni, YUAN Yuan, JING Yu, et al. Characteristics of a Severe Haze Pollution Process in Winter of 2013 and Meteorological Cause in Guanzhong of Shaanxi[J]. Journal of Arid Meteorology, 2016, 34(6):1037—1046
[6] HU Lin, CAO Hong-li, ZHANG Wen-jing, et al. Ambient air quality change and its relationship with meteorological conditions in Xi'an [J]. Journal of Meteorology and Environment, 2013, 29(6):150-153.
[7] Yue Hui. Analysis of temporal and spatial distribution characteristics of air pollutants in Xi'an [J]. Science Technology and Engineering, 2018, 18(22):318—325
[8] Liu Kai, Wang Rui, Qiu Gang. The variation of PM2.5 concentration in Xi'an in 2013 [J]. Environmental Pollution and Prevention, 2015; 37(4): 66—70
[9] Ministry of environmental protection, Technical Regulation on Ambient Air Quality Index (on trial): HJ633—2012 [S]. BeiJing: China Environmental Publishing Group.
[10] Ministry of environmental protection, Ambient air quality standards GB3095—2012 [S]. BeiJing: China Environmental Publishing Group.
[11] Hu Qinghua, Chen Xiaqiu, Zhang Fuwang, et al. Impacts of fireworks burning on the composition of PM2.5 in the atmosphere of Fuzhou [J]. Environmental Science & Technology, 2019, 42(S2):223-231
[12] Xiong Qiu-lin, Zhang Ru-xin, Ning Wen-li, et al. Study on the effect of fireworks ban on urban air quality in Jiangxi province during Spring Festival [J]. Journal of East China University of Technology (Natural Science), 2020, 43(3): 280-287.
[13] Wang Zhanshan, Li Yunting, Sun Feng, et al. Study on the Effect of Burning of Fireworks on Air Quality in Beijing [J]. Environmental Monitoring in China, 2016, 32(4): 15-21
[14] Yang Zhiwen, WU Lin, Yuan Jie. Effect of fireworks on the air quality during the Spring Festival of 2015 in Tianjin City [J]. China Environmental Science, 2017, 37(1): 69-75
[15] Hu Bingxin, Duan Qingchun, Liu Shijie, et al. Assessment of the effect of fireworks prohibition in Beijing, Tianjin, Hebei and its surrounding areas during the Spring Festival 2018 [J]. Research of Environmental Sciences, 2019, 32(02): 203-211
[16] Wang Zhanshan, Zhang Dawei, Li Yunting, et al. Analysis of Air quality in Beijing city during Spring Festival period of 2014[J]. Acta Scientiae Circumstantiae, 2015, 35(2): 371-378
[17] Zhao Wei, Fan Shaoyia, Xie Wenzhang, et al. Influence of burning fireworks on air quality during the Spring Festival in the Pearl River Delta[J]. Environmental Science, 2015, 36(12): 4358-4365
[18] Standing Committee of Xi'an Municipal People's Congress. Regulations of Xi'an on the safety management of selling and setting off fireworks and firecrackers [EB/OL] (http://police.xa.gov.cn/zgwq/zfwj/bmwj/5dbabc0b65c0d804ff6a1d8c4.html)