Holiday effect of sulfur dioxide concentration in Sanming City, Fujian Province

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Abstract. Sulfur dioxide (SO\(_2\)) is a common air pollutant. Excessive SO\(_2\) can have adverse effects on human health. SO\(_2\) emissions are not only affected by industrial production, but also from people's daily life. This study used the daily data of sulfur dioxide in Sanming City from 2015 to 2018 to analyze the holiday effect on the SO\(_2\) concentration in Sanming City. The results showed that the concentration of summer and autumn working days in Sanming City is greater than that of holidays; the concentration of holidays in spring and winter is higher than that of working days. The proportion of sulfur dioxide concentration in the Spring Festival holiday in the year of 2015-2017 is increasing year by year. This study reveals the holiday effect of sulfur dioxide concentration in Sanming City, which has important practical significance for controlling sulfur dioxide pollution in Sanming City and improving the quality of local atmospheric environment.

1. Introduction

Sulfur dioxide (SO\(_2\)) is a common air pollutant. Excessive concentrations of sulfur dioxide can cause respiratory disease to occur [1-2]. In addition, excessive SO\(_2\) can also affect fetal development and even lead to deformity [1-2]. With the development of the economy, the air pollution caused by SO\(_2\) has gradually attracted attention [3].

Sanming City, Located in the middle of Fujian Province, is a new industrial city. Among them, Sanming Iron and Steel Company, Sanming Cement Company and Sanming Chemical Company are the main sources of government revenue in Sanming City. According to statistics, in 2015, the total emissions of sulfur dioxide and nitrogen oxides in Sanming City were 41,285 tons and 37,442 tons respectively, of which industrial sulfur dioxide and nitrogen oxide emissions were 37,567 tons and 30,843 tons respectively. For industrial production behavior, the energy structure of Sanming City is mainly coal, thus Sanming City is mainly polluted as the coal type pollution. According to governmental statistics, the annual coal consumption in Sanming City is nearly 1.8 million tons. In addition, the quality of coal is poor, the content of ash is high, the equipment for burning is relatively old, further, people have poor environmental awareness [4-5], and the industrial production is basically with no desulfurization device, resulting in excessive SO\(_2\) emissions in this city.

Although as the greenest city in the greenest provinces, the problem of air pollution in Sanming can not be ignored. We speculate that illegal emissions from holidays are one of the main reasons for SO\(_2\) emissions in Sanming City. Therefore, this study can not only reveal the change law of local sulfur dioxide by exploring the holiday effect of sulfur dioxide concentration in Sanming City, but also
have important practical significance for controlling the sulfur dioxide pollution in Sanming City and improving the local atmospheric environment quality.

2. Materials and methods
This study collected daily data of SO$_2$ in Sanming City from January 6, 2015 to December 31, 2017. The research data comes from Sanming City Environmental Protection Bureau. The monitoring data points are the following four monitoring stations: Sanming Steel, Sanming No. 2 Middle School, Sanyuan District Government and Yangxi. No missing data were detected. This paper mainly analyzed the comparison of the changes in SO$_2$ concentration between working days and weekends on all weekends and statutory holidays in 2015-2017.

3. Results

3.1. Descriptive statistics of SO$_2$ concentration in Sanming City from 2015 to 2017
Table 1 shows the descriptive statistics of SO$_2$ concentration in Sanming during 2015-2017. The greatest median concentration of SO$_2$ was in 2015, with a median sulfur dioxide concentration of 15.3 ug/m$^3$, followed by 2016 and 2017, with a median of 12.8 ug/m$^3$ and 11.9 ug/m$^3$, respectively. The overall SO$_2$ concentration implied a downward trend. The pattern of average of sulfur dioxide concentration in Sanming City during 2015-2017 is basically similar to the median values. In 2015-2017, the highest concentration of SO$_2$ in Sanming City was 69.3 ug/m$^3$ in 2015.

| Year | Minimum | 1st Quartile | Median | Average | 3rd Quartile | Maximum |
|------|---------|--------------|--------|---------|--------------|---------|
| 2015 | 4.8     | 11.7         | 15.3   | 17.8    | 20.9         | 69.3    |
| 2016 | 4.7     | 10.3         | 12.8   | 13.6    | 16.1         | 34.0    |
| 2017 | 5.2     | 9.6          | 11.9   | 12.6    | 14.7         | 39.2    |

3.2. SO$_2$ concentration in holiday and working days in Sanming City in 2015

Figure 1 shows the comparison of SO$_2$ concentration between the working days and holidays in 2015. In 2015, the period average concentration in spring working days and holidays were 14.9 ug/m$^3$ and 17.6 ug/m$^3$, respectively. The monthly average concentrations in summer working days and holidays were 14.1 ug/m$^3$ and 13.2 ug/m$^3$, respectively. The monthly average concentrations in autumn working
days and holidays are 16.5 ug/m$^3$ and 15.2 ug/m$^3$ respectively. The monthly average concentrations of winter working days and holidays are 24.4 ug/m$^3$ and 28.2 ug/m$^3$ respectively. The average monthly concentration of the spring working days in 2015 is 18.1% lower than that in the holidays. The monthly average concentration in the summer working days of 2015 is 6.9% greater than that in holidays. The monthly average concentration in the autumn working days of 2015 is 8.6% higher than that in the holidays. The monthly average concentration in winter work days in 2015 is 15.6% lower than that in the holidays.

3.3. SO$_2$ concentration in holiday and working days in Sanming City in 2016

Figure 2 shows the comparison of SO$_2$ concentration between the working days and holidays in 2016. In 2016, the period average concentration in spring working days and holidays were 15.2 ug/m$^3$ and 14.2 ug/m$^3$, respectively; the monthly average concentrations in summer working days and holidays were 13.3 ug/m$^3$ and 12.1 ug/m$^3$, respectively; The monthly average concentrations in autumn working days and holidays are 11.3 ug/m$^3$ and 11.6 ug/m$^3$ respectively; the monthly average concentrations of winter working days and holidays are 14.7 ug/m$^3$ and 15.9 ug/m$^3$ respectively. To be noticed, the monthly average concentration in the summer working days of 2015 is 10.0% greater than that in holidays. The monthly average concentration in winter work days in 2015 is 5.4% lower than that in the holidays.

![Figure 2. SO$_2$ concentration in holiday and working days in Sanming City in 2016.](image)

3.4. SO$_2$ concentration in holiday and working days in Sanming City in 2017

Figure 3 shows the comparison of SO$_2$ concentration between the working days and holidays in 2017. In 2017, the period average concentration in spring working days and holidays were 11.8 ug/m$^3$ and 12.5 ug/m$^3$, respectively. The monthly average concentrations in summer working days and holidays were same. The monthly average concentrations in autumn working days and holidays are 11.6 ug/m$^3$ and 10.9 ug/m$^3$, respectively. The monthly average concentrations of winter working days and holidays are 14.2 ug/m$^3$ and 14.8 ug/m$^3$ respectively. The average monthly concentration of the spring working days in 2015 is 5.9% lower than that in the holidays. The monthly average concentration in the autumn working days of 2015 is 6.4% higher than that in the holidays. The monthly average concentration in winter work days in 2015 is 4.2% lower than that in the holidays.
3.5. *Spring Festival effect on the SO$_2$ in Sanming City, 2015-2017*

If we consider the averaged proportion of SO$_2$ in the Spring Festival should be 1.9%, when the proportion for a certain year is greater than the averaged proportion, it means that more pollution occurred. In the Spring Festival of 2015, the proportion of SO$_2$ concentration accounted for 1.8% of the whole year; the proportion of SO$_2$ concentration in the Spring Festival in 2016 accounted for 2.3% of the whole year; the proportion of SO$_2$ in the Spring Festival in 2017 accounted for 2.8% of the whole year. From the overall trend, the proportion of SO$_2$ concentration in the Spring Festival of Sanming City has increased from 2015 to 2017 (Figure 4).

4. *Discussion and conclusions*

The trends of SO$_2$ concentration in holidays and working days from 2015 to 2017 are similar with those in the four seasons of SO$_2$ concentration throughout the year. The concentration of summer and autumn working days is slightly higher than holidays; while the concentration of holidays in spring and winter is slightly higher than the working day. The proportion of SO$_2$ concentration in the Sanming City Spring Festival holiday in the year of 2015-2017 is increasing year by year.

In the spring and winter, the concentration of SO$_2$ in the working days is lower than the concentration in the holiday. Among the pollution source of SO$_2$ emission in the Sanming City, without considering the industrial production, the daily life of the citizens has a greater impact on the air pollution in Sanming City [4]. Firstly, during the Spring Festival, people will set off fireworks and
firecrackers. Secondly, the people who get married in winter are also the most in the year [5-6]. During this period, they will also burn fireworks to celebrate the wedding days. Therefore, we explained why the concentration of winter holidays will be slightly higher than the concentration of working days. Further, the results also showed that the proportion of SO\textsubscript{2} concentration in Sanming City during the Spring Festival holiday in 2015-2017 is increasing year by year. We argued that the increase of SO\textsubscript{2} concentration during the Spring Festival holiday has a great relationship with the fireworks and firecrackers. In addition, as the population of villages and towns around Sanming City gradually floods into the urban area, the number of fireworks and firecrackers is greatly increased. In addition, with the lower temperature and lower the humidity in winter, the diffusion of SO\textsubscript{2} is limited. Therefore, the concentration of SO\textsubscript{2} during the Spring Festival will increase. In addition, During the Spring Festival, the number of people out to play increased, followed by an increase in vehicle exhaust emissions.

The core weakness of this study is that we did not analyze the significant difference between the working days and the holidays. The data should be tested for the significant differences. However, due to the limitation of the data, the statistical tests for the significant differences is hard to achieve. Therefore, we merely reported the differences of our data in this study. Further, more explicit studies should be carried out.

In conclusion, in order to strictly control SO\textsubscript{2} pollution in Sanming City, it is necessary not only to increase the monitoring of industrial emission of SO\textsubscript{2}, but also to raise public awareness and maintain air quality from the public. This study can provide reference value for SO\textsubscript{2} control in Sanming City in the future.

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