Distribution Characteristics and Influencing Factors of $PM_{2.5}$ in Northern-Taiwan

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Abstract. This paper analyzes the concentration data of $PM_{2.5}$, SO_2, NO_2, CO and O_3 recorded at 25 monitoring points in northern Taiwan in 2015. The geographical distribution and seasonal changes of $PM_{2.5}$ are assessed. The geographical distribution is higher in cities than in rural areas, and higher in the west and the middle than the east. In the seasonal changes, the pollution is the most serious in spring and lightest in autumn. The author uses Pearson correlation coefficient to analyze the correlation between $PM_{2.5}$ and gaseous pollutants (SO_2, NO_2, CO and O_3). The $PM_{2.5}$ concentration in Northern-Taiwan Province has a strong correlation with SO_2, NO_2 and CO, and a weak correlation with O_3.

1 Introduction

In China, with the rapid development and weak regulations, the problem of atmospheric pollution has gradually become severe. Ambient fine particulate matter air pollution ($PM_{2.5}$), as one of the core issues of the atmospheric environment, had received international attention. Epidemiological studies have found a strong causal relationship between long-term exposure to $PM_{2.5}$ and premature death from various diseases [1]. The 2010 Global Burden of Disease Comparative Risk Assessment (GBD) pointed out that $PM_{2.5}$ is the sixth largest overall risk factor for premature death worldwide. In 2010, global $PM_{2.5}$ caused 9-3.2 million deaths. In order to better control the problem of air pollution, this paper provides some scientific basis. When controlling $PM_{2.5}$, it is necessary to consider the influencing factors of other pollutants. In this paper, the concentration data of $PM_{2.5}$, SO_2, NO_2, CO and O_3 recorded at 25 monitoring points in north Taiwan throughout 2015 were analyzed. Based on the data, the seasonal variation of $PM_{2.5}$ was evaluated, and the Pearson correlation coefficient was used to analyze the correlation between $PM_{2.5}$ and gaseous pollutants.

2 Data and Method

2.1. Research Area and Data Source

The data are from Environmental Protection Administration, Executive Yuan, R.O.C. (Taiwan) [2]. The statistical time is the whole year of 2015 and this article chooses Taipei as the research area. There are 25 monitoring stations in the territory: Banqiao, Cailiao, Datong, Dayuan, Guanyin, Guting, Keelung, Linkou, Longtan, Pingzhen, Sanchong, Shilin, Songshan, Tamsui, Taoyuan, Tucheng, Wanhua, Wanli, Xindian, Xinzhuang, Xizhi, Yangming, Yonghe, Zhongli, Zhongshan. Most of the $PM_{2.5}$ analysis is for some large inland cities like Beijing. In this paper, the author analyzes the Northern-Taiwan area in order to provide data support for the analysis of pollutants in the southern coastal area of China and some coastal areas in Southeast Asia.

2.2. Method

For comprehensive analysis for 25 sites, two classification methods are used. One is dividing the selected area into western, middle and eastern areas, according to geographical location; and the other is to divide the area into urban and rural areas.

Table 1. Regional classification using geographic location

Western area	Middle area	Eastern area
Zhongli	Datong	Keelung
Pingzhen	Shilin	Wanli
Taoyuan	Cailiao	Xindian
Longtan	Sanchong	
Guanyin	Songshan	
Guting	Wanhua	
Dayuan	Banqiao	
	Xinzhuang	

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Yonghe
Zhongshan
Lingkou
Xizhi
Tucheng
Tamsui
Yangming

Table 2. Regional classification according to urban and rural

Unban area	Rural area
Zhongli	Guanyin
Pingzhen	Guting
Taoyuan	Dayuan
Longtan	Lingkou
Datong	Xizhi
Shilin	Tucheng
Cailiao	Tamsui
Sanchong	Yangming
Songshan	
Wanhua	
Banqiao	
Xinzhuang	
Yonghe	
Zhongshan	

In the process of $PM_{2.5}$ seasonal analysis, all monitoring points in each group are selected, and the average value of the monitoring concentration is taken to represent the overall concentration level of the area. What is more, Pearson coefficient and Spearman coefficient are used to analyze the correlation between the two variables $PM_{2.5}$ and the other pollutants. When describing the correlation between two variables, the Pearson correlation coefficient is usually used. The calculation formula is as follows:

$$\rho = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

The Spearman correlation coefficient is different from the Pearson correlation coefficient. It does not need to assume the frequency distribution of variables, does not need to assume that the relationship between variables is linear, and does not need to measure variables with interval scales [3].

The calculation process could be simplified by observing the rank difference between the two variables (denoted as equation (2)). Here, n represents the number of data, and di represents the level difference between two variables.

$$\rho = 1 - \frac{6\Sigma d_i^2}{n(n^2 - 1)} \quad (2)$$

The value range of the two correlation coefficients is from -1 to 1. The greater the absolute value of the value is, the higher the correlation between the two variables is; otherwise, the correlation would be much lower [3,4].

3 Result Analysis

3.1. Space distribution characteristics of $PM_{2.5}$

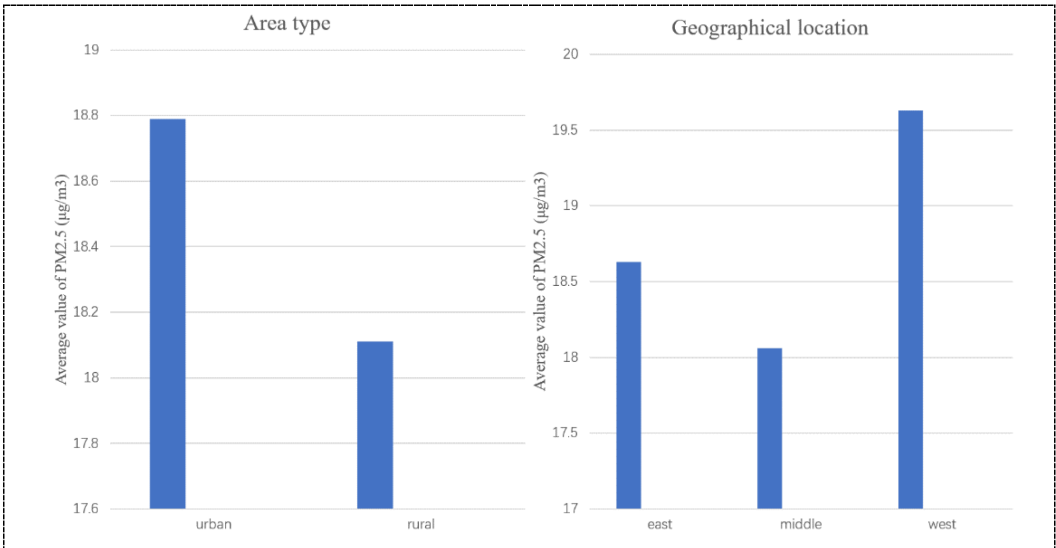

Figure 1. The annual average concentration distribution of PM2.5 according to two classification methods

As shown in figure 1, the annual average $PM_{2.5}$ concentration can be found to vary with geographical distribution. According to the World Health Organization (WHO) air quality guidelines levels, the annual mean value of fine particulate matter ($PM_{2.5}$) is recommended under 10 μg/m^3 [5]. As can be seen from figure 1, the values of all classified areas exceed the standard value. Among them, the urban index is 0.68 higher than that of the rural area, reaching 18.79 μg/m^3. In the geographical location classification, western area is up to 19.06 μg/m^3, followed by the eastern area is 18.63μg/m^3, and the middle area is the lowest which is

18.06 μg/m³. It can be seen that the annual average $PM_{2.5}$ concentration of coastal area is higher than the inland.

3.2. Seasonal distribution characteristics of $PM_{2.5}$

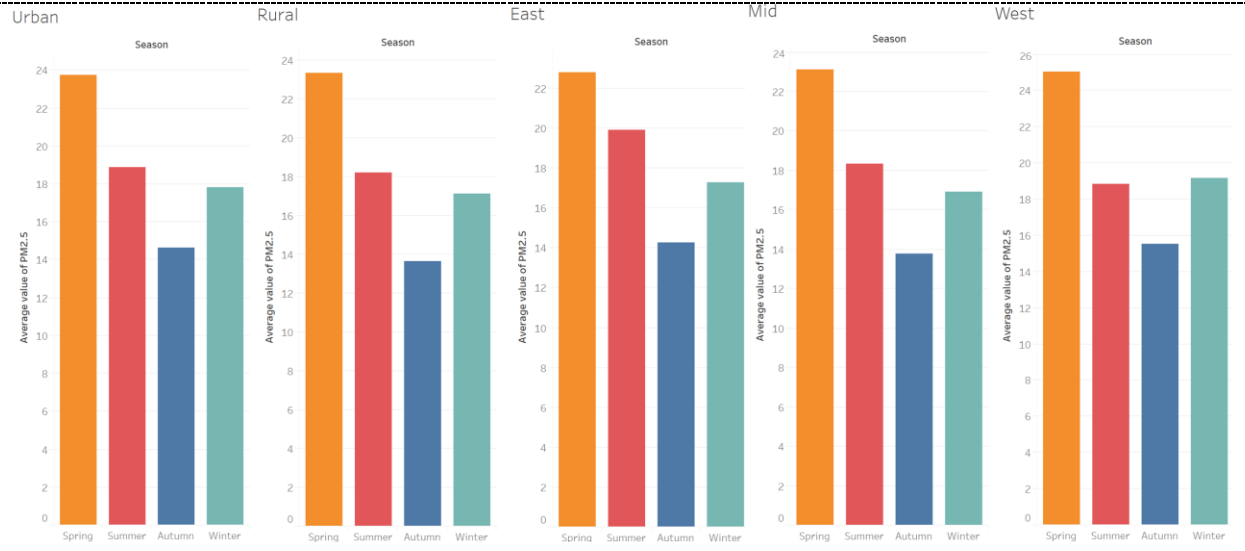

Figure 2. Seasonal distribution of annual average $PM_{2.5}$ in each classification group

From figure 2, it can be found that the annual average $PM_{2.5}$ concentration in each group shows obvious seasonal distribution, generally the highest in spring and the lowest in autumn. In addition, the results are various in different groups in summer and winter.

3.3. Correlation between $PM_{2.5}$ and gaseous pollutants

Table 3. Pearson coefficient and Spearman coefficient between the two variables $PM_{2.5}$ and the other pollutants (**Means significant correlation at 0.01 level)

Classification	Correlation coefficient	CO	NO2	O3	SO2
Urban	Pearson	0.217**	0.310**	0.168**	0.329**
	Spearman	0.297**	0.283**	0.134**	0.421**
Rural	Pearson	0.206**	0.402**	0.137**	0.132**
	Spearman	0.481**	0.411**	0.133**	0.479**
East	Pearson	0.447**	0.333**	0.208**	0.318**
	Spearman	0.469**	0.340**	0.164**	0.428**
Middle	Pearson	0.249**	0.359**	0.130**	0.321**
	Spearman	0.359**	0.361**	0.092**	0.474**
West	Pearson	0.152**	0.327**	0.185**	0.111**
	Spearman	0.331**	0.282**	0.166**	0.385**

From the data in table 3, it can be seen that the $PM_{2.5}$ concentration is significantly positive-correlated with CO, NO_2, O_3 and SO_2 on the annual scale. It has a strong correlation with SO_2, NO_2 and CO, and a weak correlation with O_3. If the Pearson coefficient is greater than the Spearman coefficient, it means that the correlation is mainly linear. On the contrary, it mainly has nonlinear relationship. In general, the $PM_{2.5}$ concentration has a nonlinear correlation with CO and SO_2, and mainly has a nonlinear correlation O_3. The linear relationship between PM2.5 and NO_2 presents different situations in different regions. From the analysis in table 3, it is obvious that the $PM_{2.5}$ concentration is mainly affected by NO_2, but the $PM_{2.5}$ concentration in some areas is mainly affected by CO and SO_2, which shows that CO and SO_2 have gradually become the main factors to affect the increase in $PM_{2.5}$ concentration. However, as a result, the $PM_{2.5}$ concentration in northern-Taiwan province has a strong correlation with SO_2, NO_2 and CO, and a weak correlation with O_3.

4 Discussion

From figure 1, it can be found that pollutants in northern Taiwan are concentrated in cities and the western region. In urban area, pollution is caused by traffic exhaust emissions, while the geographical gap may be caused by different industrial distributions. The seasonal distribution of $PM_{2.5}$ concentration in northern Taiwan is different from that in Beijing. The highest concentration turns up in spring, while Beijing has the highest concentration in winter. This may be caused by the fact that Beijing provides heating in winter, therefore the source of pollution is mainly coal combustion [6].

In northern Taiwan, such a high concentration of pollutants appears in the spring may be due to some external factors in addition to some local pollution factors. The reason for Taiwan's high spring pollutants is the long-distance transportation of pollutants from biomass burning in Southeast Asia which is caused by the climate [7]. In March, the westward expansion of the East Asian High and the Northwest Pacific Subtropical High merged and formed an organizational convergence center on the Indochina Peninsula and further development in April. The air pollutants emitted from the burning of biomass in Southeast Asia can be lifted and transported to the east immediately.

In terms of $PM_{2.5}$ prevention and control, the influencing factors of other pollutants should be considered at the same time. Among them, SO_2, NO_2 and CO should be carefully controlled. Most of CO, SO_2 and NO_2 come from four sources, including power plants, industry, residential and transportation. For different pollutants, the main sources are also different. For CO, its main source is from residential usage, accounting for about 75% of the total pollutants. The two sources that contribute most to SO_2 are the industrial and power sectors, with approximately 53% and 27% of emissions respectively, as power plants use coal with higher sulfur content to generate electricity. Industrial emissions are the largest source of NO_2 emissions, accounting for about 42%. What is more, transportation cannot be underestimated. It is the fastest growing source, increased by 62% from 1990 to 1995, which is also important to control the pollutant emissions [8].

In terms of measures to reduce pollutant emissions, the methods to reduce SO_2 emission could include using clean energy as much as possible with electricity generation, and using coal with lower sulfur content by carrying out coal washing operations when generating electricity with coal. There are also some measures to reduce NO_2 emissions. For industrial aspects, different absorption and conversion treatments are used according to the exhaust gas of different industries. In terms of transportation, the annual inspection mechanism of automobiles shall be strengthened to install more effective catalysts for automobiles. For reducing CO emissions in agriculture, the crop residues could be used for plow instead of burning them.

From the above seasonal analysis, it can be seen that not only local factors cause pollution, but also external pollution migrates with the wind. Therefore, in order to control air pollution, it is necessary to control local sources of pollution as well as work with other surrounding regions to jointly control it.

5 Conclusion

The geographical distribution is higher in cities than in rural areas, and higher in the west and the middle than the east. In the seasonal changes, the pollution is most serious in spring and lightest in autumn. Pearson correlation coefficient is used in this paper to analyze the correlation between $PM_{2.5}$ and gaseous pollutants (SO_2, NO_2, CO and O_3). Overall, the $PM_{2.5}$ concentration in northern-Taiwan province has a strong correlation with SO_2, NO_2 and CO, and a weak correlation with O_3. However, the data and methods in this article cannot analyze the source of pollutants, and it is hoped that it can be analyzed in the subsequent research.

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