The Correlation Between Temperature Inversion and Atmosphere Pollution in Beijing

Shuoyan Hua*

Nanjing Foreign Language school, Nanjing, China

*Corresponding author: huasy2004@outlook.com

Abstract. This study aimed to evaluate the correlation between temperature inversion and air pollution in Beijing, China in year 2020. The study first analyzed the monthly trend of temperature inversion levels in 2020, finding that it has two peaks in April and October and has the lowest value in August. The writer used line charts and linear regression method to study the correlation between temperature inversion level and the daily AQI level in Beijing in 2020. The study also focused on the relationship between concentration of polluting air particles: PM2.5, PM10, SO2, CO, NO2 and temperature inversion level, finding that temperature inversion level is positively correlated with the concentration of most polluting particles. The study provided comments for governments and citizens on how to reduce the effect of the air pollution caused by temperature inversion.

Keywords: Temperature inversion, AQI level, atmosphere pollution.

1. Introduction

In contemporary times, air pollution has become a serious issue all over the world. Increasing air pollution will be detrimental to people's health when they breathe in large numbers of harmful particles in the air. There are many factors that aggravate air pollution like the emission of industrial waste gases from factories and automobile exhausts. However, people always ignore an important factor that features significant character in the increase of air pollution: the climate condition. There are many climate factors that will influence air pollution and among those, one of the most essential factors is the influence of temperature inversion.

As shown in Fig. 1, temperature inversion is that in a layer of the atmosphere in troposphere, the temperature abnormally increases with increasing height while in normal times, the temperature decreases when height increases [1]. Historical events have proved that temperature inversion usually come together with serious air pollution. For example, in London between Dec. 5th to Dec. 9th in 1952, temperature inversion occurred after the appearance of cold waves, which made the temperature near ground lower than the one in higher atmosphere. At the same time period, the gases from the factories accumulated in the air, increasing air pollution and producing toxic smog, which killed over 400 citizens. From this example, it is evident that temperature inversion has very strong correlation with air pollution [2,3]. Fig. 1 below shows the diagram of the temperature inversion phenomenon and Fig.2 was the map of Beijing, indicating that Beijing is a city with advanced transportation system and industry.

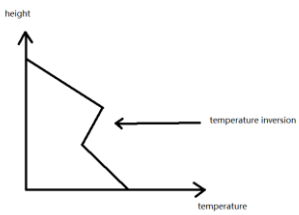

Fig. 1 Temperature inversion diagram

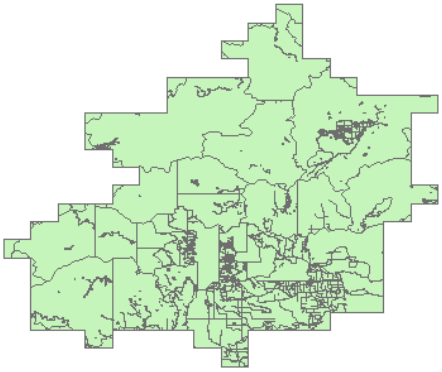

Fig. 2 The city map of Beijing

In Beijing in northern China, temperature inversion happens frequently. Also, because there are large numbers of factories around, more than 20 million people living in the city and advanced transportation system (shown in fig.2), the city suffers a lot from serious air pollution[4]. Therefore, the writer is going to analyze data related to temperature inversion and air pollution in Beijing in order to study the correlation between temperature inversion and air pollution.

2. Materials and methods

2.1. Materials

The writer collected materials about the daily temperature inversion level in Beijing in 2020 from the NASA MERRA2 satellite datasets. Temperature inversion level is the difference of temperature between the upper level of the temperature inversion zone and the lower level of the zone. When the temperature inversion level is high, it means serious temperature inversion is taking place. From the temperature inversion level data, people can clearly see on which day temperature inversion happened and how serious the temperature inversion was. The number of days when temperature inversion happened in each month in 2020 will also be generated from the data collected.

The writer also collected the daily AQI level in 2020 to see the seriousness of air pollution in Beijing. AQI level is used for judging a area's atmosphere pollution level. The higher the AQI level is, the more serious the air pollution is in the particular area. There's also need for the monthly mean AQI level and temperature inversion level data of the city to see their overall trend and correlation. In order to analyze the issue into details, monthly average concentration data about atmosphere pollutants is also needed. The writer collected the data about the daily concentration of PM2.5, PM10, SO2, CO and NO2 in Beijing in 2020 from the Chinese Air Quality Online Monitoring and Analyzing website (aqistudy.cn)

2.2. Methods

The writer is going to draw line charts of both the daily temperature inversion level and the AQI level of the city. From the chart. The writer is going to analyze the similarity and differences between the trend of the temperature inversion level and the AQI level, which can help people better understand the correlation between temperature inversion and air pollution. Also, the writer is going to calculate the monthly temperature inversion level to discover which period of the year does temperature inversion happens most frequently and seriously. Then the analysis of concentration of different pollutants and their correlation with the temperature inversion is also needed. The writer will use linear regression in order to see the correlation between days with temperature inversion in each month and the monthly AQI level and then discuss what is going to happen when there are fewer or more temperature inversion days. The graphs for the city condition (Fig. 2) are drawn by ArcGis.

3. Results and discussion

Using the daily data of temperature inversion level and AQI level in 2020, the writer made two line charts as shown in Fig.3 and Fig.4.

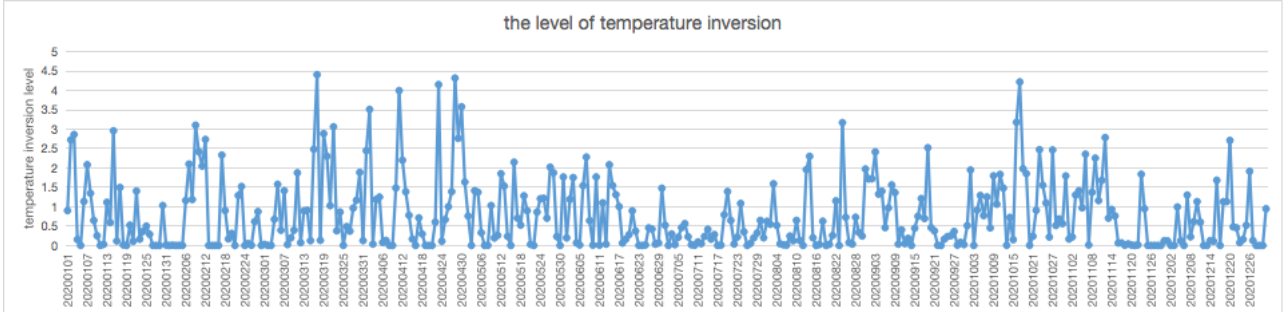

Fig. 3 The level of temperature inversion in 2020 in Beijing

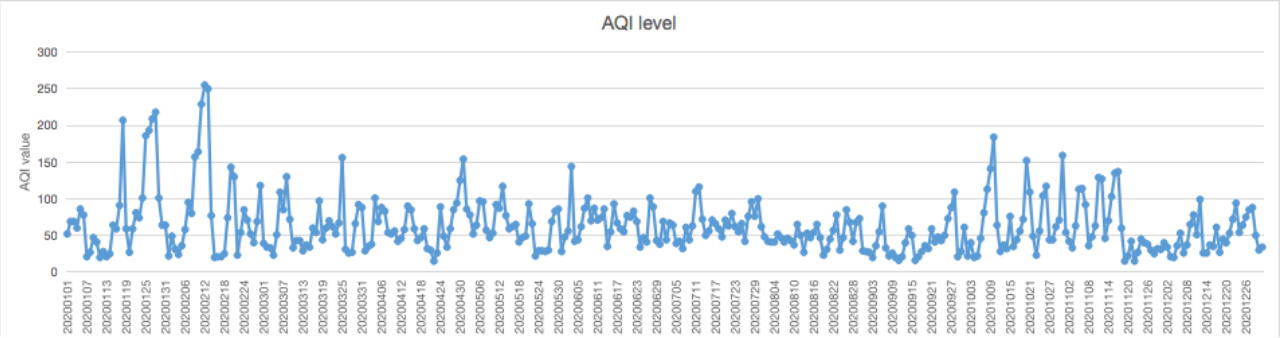

Fig. 4 The AQI level in 2020 in Beijing

From the Fig. 3 and Fig. 4, we are able to conclude that in the first few months and last few months of year 2020, both the level of temperature inversion and AQI level are higher than those in the middle of the year (especially June and July when the two levels are both at the lowest level of the year). The highest temperature inversion level occurs in April and October. Around October and April, the AQI of Beijing is also at a high level. From the graph, we can see that there may be a possibility that the low level of temperature inversion in summer cause the low pollution level and the high level of temperature inversion may also be a factor that increases the AQI level.

The analysis of some of the specific data of the year is also needed. Between Feb.8th to Feb.12th, the temperature inversion level is distinctively 1.19, 3.10, 2.41, 2.04, 2.73, all significantly higher than the average inversion level of February: 0.78, which indicates there are extremely strong temperature inversion phenomenon in that time period. The AQI level during that period is distinctively 80, 157, 164, 229 and 255 while the mean AQI level of February is 85.2, indicating that during these days, the air pollution is also very serious in Beijing. Another example is between Nov.25th to Dec 3rd, the temperature inversion level of Beijing is distinctively 0, 0, 0, 0, 0, 0.12, 0.11, 0 and 0, meaning that there was very little or no temperature inversion phenomenon happened at that time. The AQI level then is distinctively 40, 38, 30, 25, 32, 31, 40, 34 and 21, all significantly lower than the monthly average AQI level: 60.9, indicating that the air quality was good at that time. From the two examples, we can see that in time periods with serious temperature inversion, the AQI level is often higher than usual and when there is little temperature inversion, the AQI level is usually lower. This means the AQI level is positively correlated with the temperature inversion level.

Although there are some exceptions like the occurrence of high AQI level together with little temperature inversion phenomenon in January, most of the statistics can prove that air pollution has strong correlation with the temperature inversion level. Normally, temperature inversion hinders the vertical convective movement of the air and the diffusion of smoke, pollutants and water vapor condensation [5]. It just makes the lower atmosphere stable. The temperature inversion layer is like a thick quilt covering the sky above the city. The pollutants are forced to stay at certain atmosphere area and accumulate there, causing serious air pollution. The writer also calculated the monthly mean temperature inversion level and AQI level in 2020 in Beijing. The data is shown in the line charts below.

From Fig. 5, the monthly temperature inversion level is shown. We are able to find that the temperature inversion happens most frequently and seriously in April and October and is less possible to occur in summer times, especially July. Two peaks from the graph, 1.27 and 1.22 is at April and October in Spring and Autumn and the lowest point 0.31 is in July in summer. We are also able to see that the temperature inversion level in winter is higher than that in summer, indicting more pollution will be supported by the temperature inversion in winter than in summer [6]. In the whole year, the temperature inversion level will rise up when it turns to spring, then goes down in summer, rises again when autumn comes and finally decreases in winter. This makes the temperature inversion level high in spring and autumn times and lower in summer and winter times [7].

From Fig. 6, we can see the monthly average AQI level data between 2016 to 2020. We are able to find that the average AQI in summer times (especially August and September) is the lowest of the year. This fact fits with what we discover in the temperature inversion graph: the temperature

inversion level is at its lowest point in summer. This supports the conclusion that low temperature inversion level will keep less pollution in the air. Admittedly, temperature inversion is not always the deciding factor that causes atmosphere pollution. There are some other factors like the mean temperature and the usage of coal may also contribute to the air pollution.

From Fig. 6, the overall AQI level is decreasing in recent years in Beijing partly due to the government's effort in controlling pollution and the effect of the Covid pandemic on the lockout of factories and the decrease in car numbers on the road. Still, temperature inversion is extremely important in determining a city's air quality.

In order to further study the effect of temperature inversion, besides the total pollution level, the writer is also going to analyze the concentration of different types of polluting gases in the atmosphere and judge their correlation with the temperature inversion.

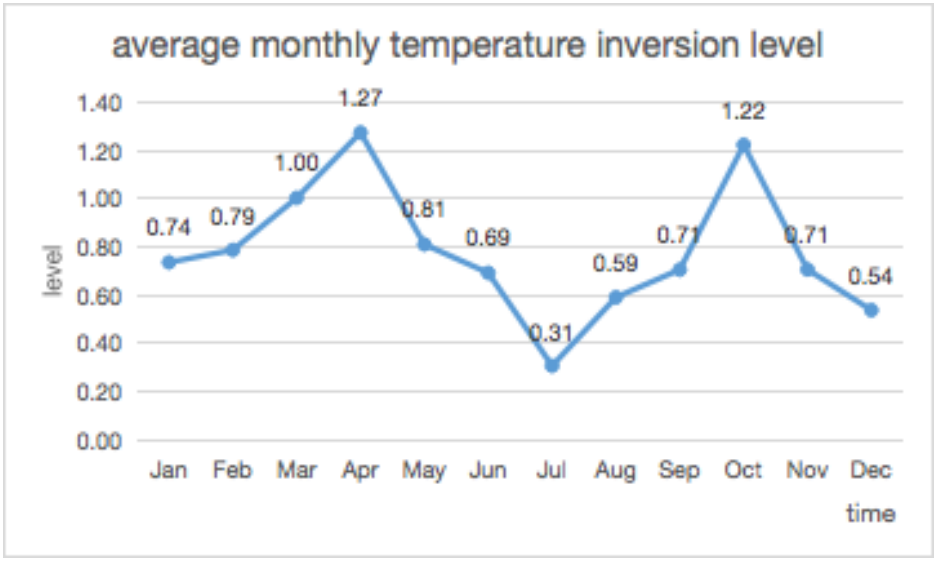

Fig. 5 The average monthly temperature inversion level in 2020

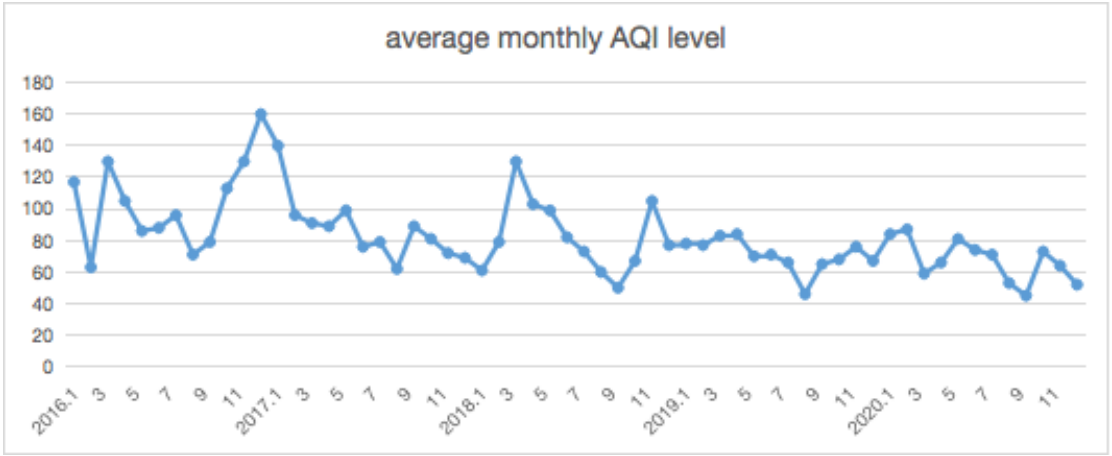

Fig. 6 Average monthly AQI level in 2020

Fig. 7 depicts the 2020 monthly average density of 5 particles: PM2.5, PM10, SO2, NO2 and CO, all of which are noxious gases [8]. The density of the gases is shown in the histogram and the average temperature inversion level is shown in the broken line. The concentration of pollutants is high between January and June and between October and December. The two peaks of temperature inversion level occur in April and October.

For PM2.5, in April and October when the temperature inversion is most serious, the level of PM2.5 is the third and fourth highest of the year. In January and February when the PM2.5 level is the highest, the temperature inversion level is also higher than the annual mean level. For PM10, in April, both the concentration of PM10 and the temperature inversion level reach the highest point of the year,

and in October, the concentration of PM10 and the temperature inversion level are the second highest of the year, only slight lower than those of April. For SO2, its concentration is higher in the first half of the year than the second half of the year, while the mean temperature inversion level in the first half of 2020(0.88) is much higher than the temperature inversion level in the second half of the year(0.68). For NO2, its concentration is at the lowest point in July when there is also the least serious temperature inversion in July. Also, in October when the temperature inversion level level is the second highest of the year, the NO2 concentration is at its highest level. For CO, similar to SO2, its concentration is higher in the first half of the year, fitting with the higher temperature inversion level. The graph below used linear regression to analyze the correlation between days with temperature inversion and the monthly AQI level or the concentration of different poisonous gases.

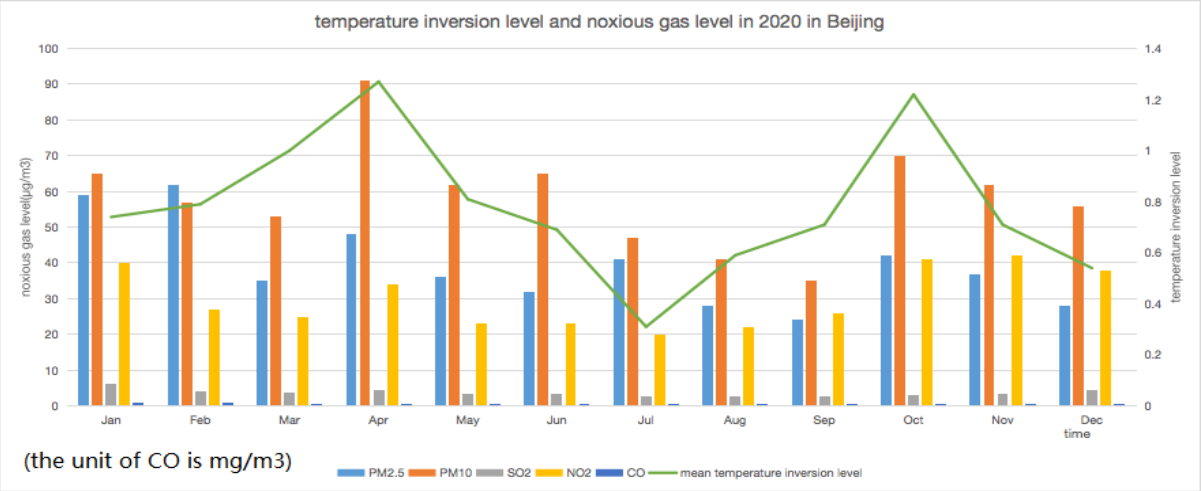

Fig. 7 Temperature inversion level and noxious gas level in 2020

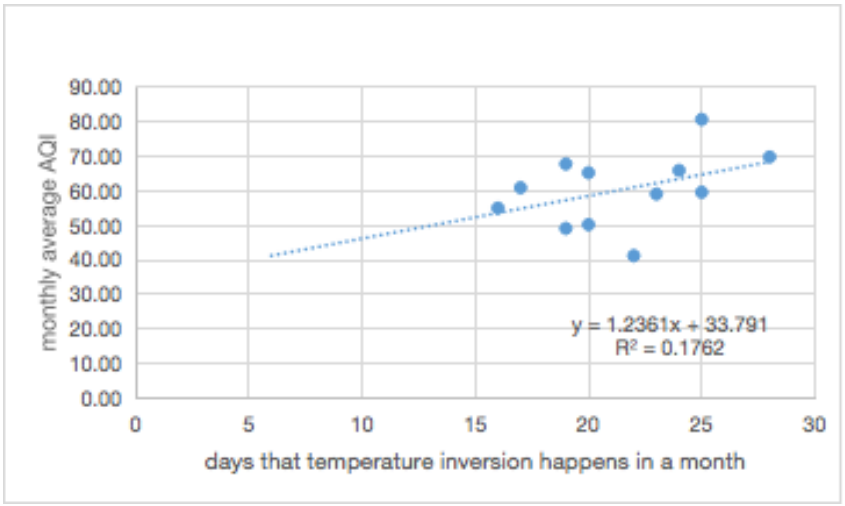

Fig. 8 AQI level linear regression

Fig. 8 shows the monthly average AQI and the number of days that temperature inversion happens in each month in 2020. Using the linear regression method to find the best-fit line, we are able to conclude that, in Beijing, the monthly AQI rises when there are more days with temperature inversion in a month. Using the best fit line, we can also predict that if there are very few days with temperature inversion, the monthly AQI level will significantly fall. The days of temperature inversion in a month is positively correlated with the monthly average AQI level.

Fig. 9, 10, 11, 12, 13 respectively shows the monthly concentration of PM2.5, PM10, SO2, NO2 and CO and the number of inversion days in each month. For PM2.5, PM10, SO2 and NO2, the monthly concentration is positively correlated with the days of temperature inversion in each month. However, CO does not show strong correlation with the temperature inversion days. The correlation between temperature inversion days per month and concentrations of PM2.5, PM10, SO2, NO2 and

CO is low because the r-square value is respectively 0.0627, 0.0948, 0.0808, 0.0509 and 0.0082, far from 1 which means perfectly correlated. However, we are still able to find that the concentrations of polluting gases are correlated with the number of temperature inversion days in a month.

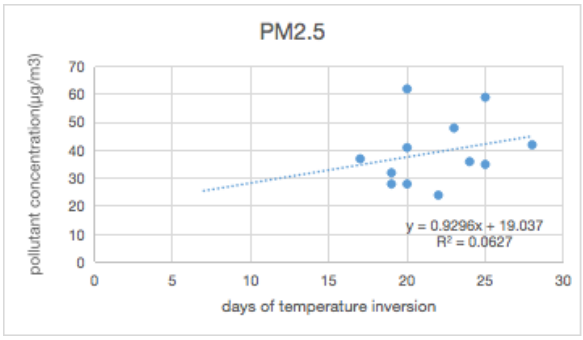

Fig. 9 PM2.5 linear regression

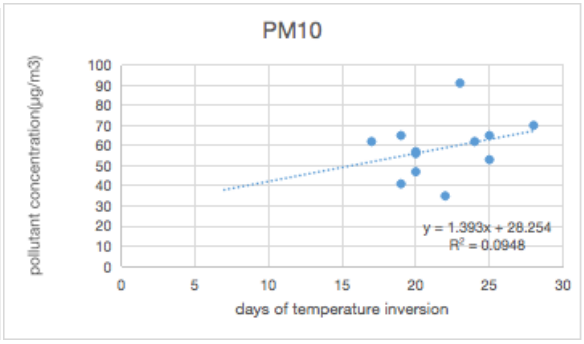

Fig. 10 PM10 linear regression

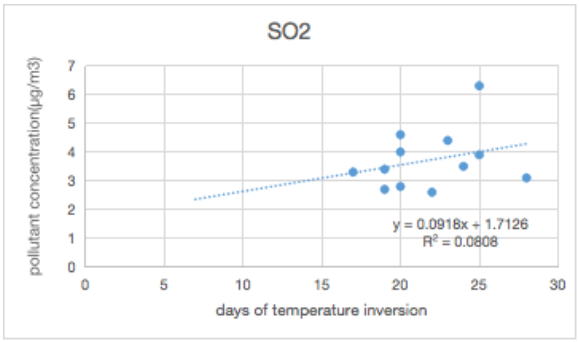

Fig. 11 SO2 linear regression

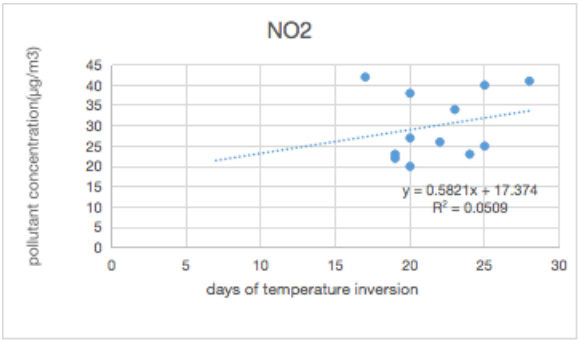

Fig. 12 NO2 linear regression

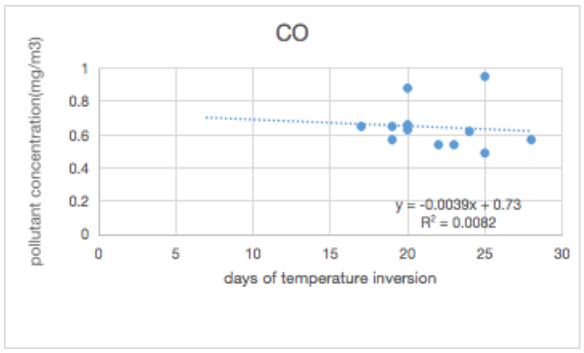

Fig. 13 CO linear regression

Based on the analysis above, we have already found the correlation between temperature inversion and air pollution in Beijing. Therefore, does the temperature inversion phenomenon that occurs in Beijing also happens in other cities? Mid-latitude regions are more prone to temperature inversions. In the area of latitude ±30°, the dry air sinks, compresses itself and heats itself. After self-heating, the air temperature in higher atmosphere is higher than the air in the lower atmosphere, which is more likely to lead to the occurrence of temperature inversion. Beijing has the latitude between 39”26’ and 41”03’north and locates in the mid-latitude area, causing temperature inversion to become a normal phenomenon of the city [9]. Temperature inversion also causes serious air pollution in other mid-latitude cities, for example, the 1952 poisonous smoke in London (51”30’ north latitude) and the 1992 air pollution in San Francisco (37”48’north latitude) were all caused by serious temperature inversion. Therefore, the air pollution caused by temperature inversion has already become a worldwide problem. In view of the adverse effects of temperature inversion, governments, institutions and residents should take particular measures when the temperature inversion occurs. For governments, they ought to monitor the climate pattern in order to forecast the time when temperature inversion will occur and the level of temperature inversion. In days when serious temperature inversion takes

place, the government can impose restrictions on factories to reduce the polluting gases released from factories and restrain the car numbers on the road in order to reduce automobile exhausts. With fewer polluting gas particles in the atmosphere, temperature inversions are less likely to cause serious pollution. Governments should also give warnings to citizens about the pollution caused by temperature inversion. For normal citizens, because temperature inversion often occurs between 6:00 at night and 8:00 in the next day morning, they should adjust their outdoor activities and ventilation time. Citizens living in areas with frequent temperature inversion can do outside activities between 10:00 and 15:00 when the temperature inversion is less serious and will not significantly aggravate air pollution [10]. In addition, when temperature inversion occurs, the indoor air pollutants emission will be blocked and poisonous CO will accumulate indoor. As a consequence, carbon monoxide poisoning has a high possibility of happening in temperature inversion times. In order to prevent this, citizens can check the exhaust pipe to make sure the poisonous gases will be successfully emitted and can open the window for ventilation if necessary.

4. Conclusion

The study sought to investigate the correlation between temperature inversion and atmosphere pollution. Data on temperature inversion levels in Beijing in 2020 showed that temperature inversion happens most frequently and seriously in April and October and it occurs most rarely in August. Depending on the analysis, temperature inversion level and AQI level is positively related. Also, the regression analysis showed that temperature inversion level is also positively correlated with the concentration of the polluting particles in the atmosphere. During the period of temperature inversions, because the air is hot on the top and cold on the bottom, it is not easy to form convection. Therefore, the air flow is not smooth; the pollutants are not easy to diffuse; and the air pollution is easy to concentrate. The study also provided comments to governments and citizens how to reduce the effect of the pollution caused by temperature inversion.

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