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Analysis of Factors Posing an Impact on Air Quality in Chengdu

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Abstract: As an inland megacity, Chengdu plays a leading role in economic development of Sichuan. In recent years, it has seen rapid economic development. With such rocketing development of economy, the environment problem is becoming increasingly predominant. This paper includes statistical analysis of the atmosphere data released by Chengdu Environmental Protection Bureau and the meteorological data released by Chengdu Meteorological Bureau, and uses various mathematical methods and models to analyze main factors that pose an impact on air quality in Chengdu. It clarifies the influencing process and reasons, and proposes some reasonable governance recommendations regarding the air pollution without prejudice to economic development.

Problem analysis

To find out the main factors that pose an impact on air quality in Chengdu, we should at first seek for such factors in the conclusions we already have, such as rainfall and temperature. Then based on the impact of such factors on the amount and change trend of the air pollutants, we will try to find out the relation of such factors with various parameters of air quality. After that, the conclusions drawn will be verified with available data. This way, we will figure out the degree of impact of various factors on air quality, and the related impacting modes.

In the first place, the relation between terrain and temperature in Chengdu will be discussed. Chengdu is located in the west part of a basin, and therefore there will be remarkable temperature inversion in spring and winter. In addition, cloud and mist easily accumulate in a basin, which means there is insufficient sunlight in the day, and the temperature rise of the ground is moderate. As such, “temperature inversion” will usually last for a long time, which may deteriorate the air pollution. Furthermore, in spring and winter, Chengdu is vulnerable to attack by cold current of the high latitude area and the ground will be dominated by cold air mass. The weather is sunny, wind is mild and temperature is low. In particular, the temperature will drop sharply because a great amount of heat is emitted (radiated) to the upper air. At the same time, the upper atmosphere temperature drops slowly, thus resulting in temperature inversion with high temperature in the upper air and low temperature on the ground.

Given such a special terrain of Chengdu, we should consider whether this factor poses a great impact on air quality, and determine the impact of this factor through analyzing and comparing the available data depending on whether there is rainfall.

In the first question, we used the analytic hierarchy process to obtain the weight of 6 pollutants and found that the weight of particulate matter is very high. Therefore, also analyzed and tried to find out important factors that result in particulate matter. For CO and NO2 which have a lower weight, we also analyzed their main emitting sources. The best way to determine their main emitting sources (pollution sources) is to collect the statistics on emission of various pollutants and

the percentage data of the emission of each pollution source in recent years. Based on those data, we could make judgment.

According to the distribution of IAQI values of air pollutants in terms of date, the overall pollution was generally serious in months with low temperature (from December to January and February of the second year). Therefore, we found it is important to figure out whether air temperature is a key factor that poses an impact on air quality in Chengdu. In the following part, data analysis will be conducted to verify the assumption. For air temperature within a certain range, we should take the median as the air temperature of the day. The changing curve of temperature data is shown in Table 11.

According to the modified AQI changing diagram, we can find that temperature is in negative correlation with AQI*, which basically coincides with what we have concluded. To make this clear, we are going to calculate the correlation coefficient between temperature and AQI.

$$r = \frac{\sum_{i=1}^{n}(T_i - \overline{T})(AQI_i - \overline{AQI})}{\sqrt{\sum_{i}^{n}(T_i - \overline{T})^2 \cdot \sum_{i}^{n}(AQI_i - \overline{AQI})^2}}$$

r: Correlation coefficient

i: The ith day

The correlation coefficient r=-0.3715, as obtained by calculation. Based on the fact that AQI is moderately correlated to temperature, we can infer that temperature is correlated to AQI. This verifies the impact of temperature on air quality. We can infer that temperature is a key factor that poses an impact on air quality.

Rainfall poses a cleaning effect on air [10] and rainfall is one of the main methods of particulate matter absorption. It can obviously reduce concentration of particulate matter in the air and transfer the pollutants onto the earth surface. This explains to a certain extent the reason that the air quality of southern cities is generally better than that of northwestern cities. We believe that rainfall also poses a significant impact on air quality of Chengdu. In addition, within a certain precipitation range, the precipitation is in direct proportion to the cleaning effect on the air pollutant.

The conclusion will be further verified as follows:

In the monitoring period of more than 500 days, the weather situation in Chengdu was very complicated. To ensure the analytical method was feasible, the complicated model was simplified. The main weather conditions were divided into rain and snow and no rain and snow. The mean values of AQI of the two conditions were both calculated.

$$\overline{AQI_r} = \frac{\sum_{i}^{n_r} AQI_{ri}}{n_r}, \quad \overline{AQI_{nr}} = \frac{\sum_{i}^{n_{nr}} AQI_{nri}}{n_{nr}}$$

AQI_{r} refers to the AQI value of a rain and snow day;

AQI_{nr} refers to the AQI value of now rain or snow day;

n_r refers to the total number of rainy and snowy days included in the monitoring data;

n_{nr} refers to the total number of non-rainy or snowy days included in the monitoring data.

Calculation results are given below:

AQI_r=82.41, AQI_{nr}=110.31

AQI_{nr} is 33.8% higher than AQI_r, which means that the impact of rainfall on air quality of Chengdu is quite significant. Rainfall can not only wash away some of the PM10 particulates in the air, but can also restrain dust from land surface, thus effectively reducing emission of PM10.

Chengdu is seated in a basin, with mountains as natural barriers on four sides, which means the airflow in Chengdu is steady, and the wind power is basically below level 3. The main directions of wind posing an adverse impact on air quality in Chengdu downtown is northeast and east, according to the planning and layout of pollution emitting enterprises of Chengdu (mainly located in east Chengdu and northeast Chengdu). In the more than 1,000 days of the 4 years, the total number of days with northeast wind and east wind was only 6 and 4 respectively. Therefore, the chance that the wind transfers pollutants generated by the enterprises to the downtown of Chengdu will be extremely low. This is attributable to the reasonable planning of enterprise layout by related authorities of Chengdu.

The wind power in Chengdu is almost lower than level 3 throughout the year, which means the wind only breeze. The wind which is lower than level 3 has a very limited diluting and dispersing effect on the pollutants in the air. Therefore, we can conclude that this is not one of the key factors that pose an impact on air quality in different areas of Chengdu.

According to data shown in Table 14, the nitrogen oxide emission of automobiles basically accounts for half of all the nitrogen oxide emission. CO and NO2 emissions of automobiles are two major pollutants for the air. Therefore we need to determine the impact of automobiles.

Firstly, analysis shows that the number of vehicles is closely related to the automobile emission amount, and the relation is a rough linear relation. Assume the number of vehicles is x, and the annual automobile pollutant emission amount is y. The research method adopted by Fuzhou City for impact of automobiles in the downtown on air pollution was taken as an example. As the emission standard of automobiles is generally the same all over China, the distribution of automobile models with different displacements is of reference value.

The function model of relation between the number of automobiles and the automobile pollutant emission amount is as follows:

$$y = ax + b$$

The unary linear regression analysis method is used:

$$b = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - (\sum x)^2}, \quad a = \frac{\sum y}{n} - b\frac{\sum x}{n}$$

x refers to the number of automobiles;

y refers to the automobile pollutant emission amount (10,000 tons);

n refers to the number of data sets used for calculation.

The equation obtained from calculation is as follows:

y=5.391666+0.000122x

This means that on an average, each automobile will generate pollutant emission amount of 1.22 tons.

What should be noted is that the standard for automobile pollutant emission used by Fuzhou City

is still the stage-3 emission standard of China. However, according to the announcement on implementation of stage-IV standard for automobile pollutant emission of China in Chengdu issued by Chengdu Environmental Protection Bureau and Chengdu Traffic Management Bureau, Chengdu started implementation of the stage-IV standard for automobile pollutant emission of China in 2011. From 2013 on, the compression ignition lightweight cars failing to meet the national stage-IV standards could not be sold or registered. According to the requirement of the stage-IV standard for automobile pollutant emission of China as shown in Appendix II, the exhaust pollutant emission of each automobile will be reduced to half of that specified in the previous stage-III national standard. The above equation is revised as follows:

$Y=5.391666+0.000061x$

Which means that every single automobile will generate pollutant emission amount of 0.61 tons.

From 2013 on, the average number of newly registered automobiles was 1,874 for working days. Assume that this number remained steady from then on. According to No. 270 Order of the State Council of the People's Republic of China, the number of public holidays was increased from 7 to 10. As such, the number of working days each year can be calculated as follows:

365/year – 104 days/year (day off) – 10 days/year (public holiday) = 251 days/year

Usually, we assume the number of working days is 250. Then the average number of newly increased automobiles each year can be calculated as follows:

$1874\times250=468500$

The newly increased amount of pollutant emission each year can be calculated as follows:

$P=0.000061\times468,500=285,785$ tons

The main automobile exhaust pollutant is carbon monoxide and nitrogen oxides. Based on the figures, the automobile pollutant emission amount is enormous. However, the pollution of air quality it causes is not reflected directly in the monitoring data (which means that the air pollution index is not increasing with increase of the number of automobiles in Chengdu). This is because that Chengdu has been devoting great efforts to controlling and treatment of air pollutants and the impact of automobile emission on air quality can be mitigated.

According to the weight matrix W we have obtained using the analytic hierarchy process, we can find out that SO2 and particulate matter have the highest weights. The pose the greatest impact on air quality, and therefore it is necessary to analyze their emission.

The emission information of SO2 is shown in Table 15. According to Table 14, we can figure out that the amount of SO2 and NO2 emitted by industrial sources accounts for more than half of the total amount. Then we can conclude that industrial source is the main factor that poses an impact on air quality. The main source of particulate matter is the fume. According to the fume emission in Chengdu in 2013, the industrial fume accounted for 83.5% of the total; household fume accounted for 2.6% and the automobile fume accounted for 12%. It can be seen that industrial source is the main factor that poses an impact on the air quality.

To improve the air quality in Chengdu, we have formulated the following suggestions:

(1) Industrial production

1. Technical improvement should be implemented and emission limit should be imposed for high-pollution enterprises; related enterprises should use desulphuration equipment and high-efficiency dust removing equipment, and adopt low ammonia burning and denitration technology to reduce emission of pollutants.

2. Industrial layout should be controlled strictly. Enterprises to settle down in Chengdu should be strictly screened according to the economic development need of Chengdu and the bearing capacity of the environment of Chengdu.

3. The total amount of pollutant emission should be taken as the prerequisite for enterprises to pass the environmental assessment. The total emission amount should be used to evaluate the project. In addition, strict review should be carried out for petrochemicals, chemicals, cement, non-ferrous project and coal fired boiler.

4. Clean production should be promoted among enterprises; emission of fugitive organic gasses should be controlled during the technological process for petrochemical, painting, printing ink, adhesive, spraying and coating enterprises.

5. Supervision of gas emitting manufacturers should be strengthened. The dynamic data on emission of pollutants by industrial enterprises should be collected; industrial enterprises with emission or total emission amount exceeding the limit should be asked to take remedies within a time limit. Those failing to take such remedies within the time limit should be shut down by the government. If the standards are met but the total amount of emission is still exceeded, in-depth control and treatment should be carried out to reduce the total emission of pollutant.

(2) Management of automobile emission

1. Public transportation should be promoted; rail transit construction should be expedited; the percentage of special lane for buses in the city center roads (including bus rapid transit) should be increased. A reasonable tolling standard should be established to encourage citizens to choose the public transportation means.

2. The odd-and-even-number rule should be implemented for automobiles; all automobiles in Chengdu should meet the national standard for emission. To restrain the rapid increase of number of automobiles, restriction of purchase may be imposed.

(3) Control of dust pollution

1. Asphalt pavement should be provided for all newly built roads; the building wastes in Chengdu should be transported in containers in a fully sealed way. The transportation of wastes against regulations at night should be punished strictly.

2. Monitoring of construction site should be strengthened. No illegal cutting of building materials is allowed on the construction site. On site bending of concrete and mortar is not allowed. Temporary road used for transportation of earth should be hardened and washed regularly. The exit and entrance access road of the special temporary piling yard for earth should be hardened and provided with vehicle washing facilities.

The integrated flushing and sweeping equipment should be used to clean the road. The frequency of road flushing should be increased to reduce accumulation of dust.

1. Monitoring of cooking oil fume should be strengthened; outdoor barbecue should be prohibited. The catering enterprise should install effective oil fume purifying facility according to the standards for city center.

2. Illegal sales of fireworks and crackers should be cracked down upon; the categories of fireworks and crackers should be strictly controlled; the discharge of fireworks and crackers should be managed according to the time and place; citizens should be encouraged to set off the fireworks and crackers in a safe way.

3. Punishment for burning of straw in the open air and refuses in the city area should be increased.

4. Public propaganda and education of environmental protection should be strengthened to encourage citizens to participate in the environmental campaigns. Extensive propaganda of scientific knowledge of air pollution control and propaganda of knowledge of environmental protection should be carried out, in an effort to promote “green living” mode that relies on energy

conservation, economy, use of public transportation, elimination of burning in the open air, and use of green and environmental friendly paints for house decoration. This way, the citizens will develop a habit of green travel, green consumption and green living.

(5) Measures in other processes

1. A regular artificial precipitation operation mechanism should be established; artificial precipitation should be organized in time when the conditions are met to increase humidity of the air.

2. Burning of raw coal (bulk coal), washed coal, honeycomb briquette, coke and charcoal should be banned in surrounding districts and counties of Chengdu; burning of inflammable wastes and direct burning of biomass fuel, as well as high-pollution fuels with pollutant content exceeding the national regulations, such as diesel, kerosene and artificial gas, should be banned; in addition, daily monitoring of the burning area should be strengthened; punishment imposed on burning of high-pollution fuels should be strengthened.

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