Research on the Changes of Air Quality in Chengdu During the COVID-19 Pandemic

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Abstract. As a public health emergency, COVID-19 has greatly affected all walks of life. It also has an impact on the environment. In order to systematically assess the impact of COVID-19 on the environment and the reasons for this impact, this paper takes Chengdu as an example for research. The air quality in Chengdu is analysed from two aspects of time and space, two dimensions of longitudinal and transverse. This paper selects six air pollution indexes (PM2.5, PM10, NO2, CO, SO2, O3) and applies the dual-weight fuzzy comprehensive evaluation method to analyse. The results show that, no matter what the angle is, the air quality in Chengdu has greatly improved during the COVID-19 blockade and the concentration of various pollutants has been greatly reduced. But it's worth thinking about that this situation is always temporary from a longitudinal perspective. With the unblocking and the restoration of industrial production, the air pollution situation begins to return to previous state. This paper provides a reference for studying the changes in air quality during the COVID-19 pandemic and provides a useful supplement for air pollution control.

1. Introduction
In recent years, the economies of all countries have been developing and great achievements have been made in many aspects. But these countries are facing the rapid deterioration of the environment, including air pollution and other serious problems[1]. Many scholars focused on the study of air quality. Since the last century, air quality monitoring system has obtained a large number of air pollution index data. The air pollution level of an area could be expressed by Air Quality Index (AQI), Pollution Index (PI), and so on[2]. And scholars gradually adopted various evaluation methods to evaluate air quality. For example, Ibrahim Demir used the fuzzy comprehensive evaluation method to study the air quality of Istanbul[3]. Yuan Yan evaluated economic development and air pollution by DEA method[4]. Zhou Zhixiang constructed a DEA window analysis model to evaluate air quality in China[5].

Clearly, the COVID-19 pandemic has had a significant impact on air quality. This phenomenon has also attracted the attention of scholars around the world. Susanta Mahato used NAQI to study Delhi's air pollution during the COVID-19 pandemic[6]. Muhammad Sulaman discussed the impact of COVID-19 on air pollution through a review of NO₂ data from cities in Wuhan, Italy, Spain and the United States[7]. Guilherme Dantas discussed the impact of the COVID-19 pandemic on air quality in Rio de Janeiro through obtained concentrations of particulate matter, CO, CO₂ and O₃[8]. Academics are looking at changes in air quality during the COVID-19 pandemic with their own unique perspectives. There has been little research on air quality in China during the COVID-19 pandemic.
Therefore, this paper takes Chengdu as an example to study air quality in China during the COVID-19 pandemic.

In the process of studying the influence of COVID-19 on air quality in Chengdu, six air pollution indexes were selected and the dual-weight fuzzy comprehensive evaluation was applied for the study. This paper stipulated the pre-blockade, during-blockade, post-blockade period based on relevant policies. In this paper, we considered the pre-blockade, during-blockade, post-blockade as longitudinal dimensions. And from the time longitudinal and space longitudinal two aspects to analyse. Meanwhile, the during-blockade period in 2020 was compared with the same period in 2019. This could be viewed as an analysis from the transverse dimension. Transverse dimension could be divided into two aspects of time transverse and space transverse. Finally, the results of this paper were summarized.

2. Methods and materials

2.1. Dual-weight fuzzy comprehensive evaluation method

Based on the summary of the application methods of many scholars in the study of air quality problems, this paper selected the dual-weight fuzzy comprehensive evaluation method to study. The model mainly included five steps.

2.1.1. Determine index set and appraisal sets.

Supposed that air quality has $n$ evaluation factors, i.e., the index set is $U = \{u_1, u_2, \ldots, u_n\}$. $i$ is generally used to represent the evaluation factors, $i = 1, 2, \ldots, n$. And air quality has $m$ levels, i.e., the appraisal set is $V = \{v_1, v_2, \ldots, v_m\}$. $j$ is used to represent the level, $j = 1, 2, \ldots, m$. According to the Environmental Air Quality Standard (GB3095-2012), this paper determined that air quality evaluation factors included PM2.5, PM10, NO2, CO, SO2, O3. And air quality levels included excellent(I), good(II), light pollution(III), moderate pollution(IV), severe pollution(V), serious pollution(IV).

2.1.2. Determine the membership degree.

$r_{ij}$ is the fuzzy membership degree of factor $i$ to level $j$. The membership function of reduced half trapezoidal slope distribution was selected in this paper and the expression are as follows:

The membership function of the $i$th evaluation factor for the level $j$ ($j = 1$) is:

$$r_{ij} = \begin{cases} 1 & x_i \leq S_{ij}(1) \\ 1 - \frac{x_i - S_{ij}(2)}{S_{im}(1)} & S_{ij}(1) < x_i \leq S_{ij}(2) \\ 0 & x_i > S_{ij}(2) \end{cases}$$

The membership function of the $i$th evaluation factor for the level $j$ ($j = 2, 3, \ldots, m-1$) is:

$$r_{ij} = \begin{cases} 1 + \frac{x_i - S_{ij}(1)}{2S_{im}(1)} & x_i < S_{ij}(1) \\ 1 & S_{ij}(1) \leq x_i \leq S_{ij}(2) \\ 1 - \frac{x_i - S_{ij}(2)}{S_{im}(1)} & x_i > S_{ij}(2) \end{cases}$$

The membership function of the $i$th evaluation factor for the level $j$ ($j = m$) is:

$$r_{ij} = \begin{cases} 1 + \frac{x - S_{ij}(1)}{2S_{im}(1)} & x_i < S_{ij}(1) \\ 1 & S_{ij}(1) \leq x_i \leq S_{ij}(2) \end{cases}$$

notes: $S_{ij}(1)$, $S_{ij}(2)$ respectively represent the lower limit and upper limit standard of the $j$th level of the $i$th evaluation factor, $S_{im}(1)$ represent the referral standard value of the $m$th level (the highest level) of the $i$th evaluation factor. When $r_{ij}$ is negative, $r_{ij} = 0$.  


2.1.3. Establish the fuzzy relation matrix $R$.
The membership degree of each evaluation factor to each level is calculated according to (1) - (3). Where $R$ is the fuzzy relation matrix:

$$
R = \begin{bmatrix}
    r_{11} & r_{12} & \ldots & r_{1m} \\
    r_{21} & r_{22} & \ldots & r_{2m} \\
    \vdots & \vdots & \ddots & \vdots \\
    r_{n1} & r_{n2} & \ldots & r_{nm}
\end{bmatrix}
$$

2.1.4. Construct weight vector.
The influence of each evaluation factor is not equally important on the evaluation result. Therefore, it is necessary to assign different weight to each evaluation factor. The weight was determined by exceeding standard method, and the toxicity of evaluation factors was added on this basis. The toxicity index was shown in the table 1:

| Evaluation factors | PM2.5 | PM10 | SO₂ | CO   | NO₂ | O₃ |
|-------------------|-------|------|-----|------|-----|----|
| Toxicity index    | 1     | 2    | 5   | 5    | 4   | 3  |

The weight formula of the $i$th index calculated by exceeding standard method is as follows:

$$
C_i = \frac{x_i}{\sum_{j=1}^{m} S_{ij}/m} / \sum_{i=1}^{n} \left[ \frac{x_i}{\sum_{j=1}^{m} S_{ij}/m} \right] \quad (4)
$$

The weight calculation method after considering toxicity is as follows:

$$
a_i = \frac{C_i}{f_i} / \sum_{i=1}^{n} \frac{C_i}{f_i} \quad (5)
$$

notes: $f_i$ is the toxicity index of the $i$th evaluation factor, and $a_i$ represents the weight value of the $i$th evaluation factor. The final weighted set is:

$$
A = (a_1, a_2, a_3, a_4, a_5, a_6) \quad (6)
$$

2.1.5. Determine evaluation results.
The dual-weight fuzzy comprehensive evaluation result is obtained through the above calculation. The principle of maximum membership is adopted to determine the level of evaluation results.

2.2. Data collection
First, from 7 January to 23 January was defined as the pre-blockade period, from 24 January to 9 February was defined as the during-blockade period, from 10 February to 26 February was defined as the post-blockade period. Secondly, when analysed from the longitudinal dimension of time, the daily average data of evaluation factors during the pre-blockade, during-blockade and post-blockade period in 2020 were compared. For the analysis in the transverse dimension of time, the daily average data of evaluation factors during the blockade period in 2019 and 2020 were used for comparison. Finally, when analysis from the longitudinal dimension, this paper combined 8 air quality monitoring stations covering different areas of Chengdu (Jinquanlianghe, Shilidian, Sanwayao, Shahepu, Junping Street, Lingyan Temple, Dashi West Road and Longquanyi District government). From the longitudinal dimension of space, the daily average data of evaluation factors monitored by each monitoring station in the pre-blockade, during-blockade and post-blockade period in 2020 were selected for comparative analysis. When analysed from the transverse dimension of space, the daily average data of evaluation factors monitored by each monitoring station during the blockade period in 2019 and 2020 were selected. Air quality evaluation factors data were obtained from China National Environmental Monitoring Centre.
3. Results and discussion

3.1. Longitudinal Dimension

3.1.1. The Longitudinal Dimension of Time.
Table 2 was the daily air quality level of Chengdu in the pre-blockade, during-blockade and post-blockade period in 2020 calculated by the double-weight fuzzy comprehensive evaluation method. The changes of air quality of Chengdu in the longitudinal dimension of time was studied.

Table 2. Air quality level in the longitudinal dimension of time

| Pre-blockade period | During-blockade period | Post-blockade period |
|---------------------|------------------------|----------------------|
| Jan 7th             | II                     | Feb 10th             |
| Jan 8th             | II                     | Feb 11th             |
| Jan 9th             | II                     | Feb 12th             |
| Jan 10th            | I                      | Feb 13th             |
| Jan 11th            | II                     | Feb 14th             |
| Jan 12th            | II                     | Feb 15th             |
| Jan 13th            | II                     | Feb 16th             |
| Jan 14th            | III                    | Feb 17th             |
| Jan 15th            | II                     | Feb 18th             |
| Jan 16th            | II                     | Feb 19th             |
| Jan 17th            | II                     | Feb 20th             |
| Jan 18th            | II                     | Feb 21th             |
| Jan 19th            | II                     | Feb 22nd             |
| Jan 20th            | II                     | Feb 23th             |
| Jan 21th            | III                    | Feb 24th             |
| Jan 22th            | III                    | Feb 25th             |
| Jan 23th            | III                    | Feb 26th             |

According to analysis, Chengdu’s air quality had level I days accounted for 6%, level II days accounted for 70%, and level III days accounted for 24% at the pre-blockade period. The percentage of days with level I air quality in Chengdu was 18%, and the percentage of days with level II air quality was 82% at the during-blockade period. At the post-blockade period, Chengdu’s air quality had level I days accounted for 6%, level II days accounted for 58.8%, and level III days accounted for 35.2%. Through comparing before and after the blockade, which could get a clear air quality at the during-blockade period in level I and II. The light pollution had appeared in pre-blockade period and post-blockade period, and the proportion was as high as 25% above.

3.1.2. The Longitudinal Dimension of Space.
In order to more visually express the improvement of air conditions in various regions of Chengdu at the during-lockdown period, this paper used the dominant air quality pollution index (PM2.5, PM10 and NOx) to depict the changes of air quality conditions in the pre-blockade, during-blockade and post-blockade period in 2020 (figure 1-3).

By observing PM2.5 (figure 1) and PM10 (figure 2), it could be clearly seen from the spatial pattern of these two pollutants that the concentration of PM2.5 and PM10 at the during-blockade period was significantly lower than that before and after the blockade. Because the main sources of
PM2.5 and PM10 in Chengdu were industrial activities, construction work and suspended solids such as dust. During the lockdown, Chengdu followed relevant national policies to prevent and control the epidemic. A large number of enterprises and construction projects were suspended. As a result, pollution sources were controlled. Meanwhile PM2.5 and PM10 concentrations were reduced. But it is worth noting that the concentration of the two pollutants began to rise gradually with the resumption of work and production on February 9, and traffic began to resume.

Figure 1. Change in PM2.5 in the Chengdu during Jan 7th to Feb 26th

Figure 2. Change in PM10 in the Chengdu during Jan 7th to Feb 26th
3.2. Transverse Dimension

3.2.1. The Transverse Dimension of Time.
To further complement the views in the previous section, this paper explored the comparison between the during-blockade period in 2020 and the same period in 2019. Table 3 was the daily air quality level of Chengdu at the during-lockdown period in 2020 and 2019 calculated by the dual-weight fuzzy comprehensive evaluation method.

Table 3. Air quality level of Chengdu at the during-lockdown period in 2020 and 2019

| Date       | 2019 | 2020 | Date       | 2019 | 2020 |
|------------|------|------|------------|------|------|
| Jan 24th   | III  | II   | Feb 2nd    | II   | II   |
| Jan 25th   | III  | II   | Feb 3rd    | II   | I    |
| Jan 26th   | III  | II   | Feb 4th    | II   | I    |
| Jan 27th   | II   | II   | Feb 5th    | III  | II   |
| Jan 28th   | II   | II   | Feb 6th    | III  | I    |
| Jan 29th   | II   | II   | Feb 7th    | II   | II   |
| Jan 30th   | II   | II   | Feb 8th    | II   | I    |
| Jan 31th   | II   | II   | Feb 9th    | II   | II   |
| Feb 1st    | II   | I    |            |      |      |

According to the statistical analysis of the air quality level of Chengdu in 2020, the number of days in level I accounted for 17.7%, and the number of days in level II accounted for 82.3%. In the same period of 2019, the number of days in Chengdu's air quality was 0 for level I, 70.6% for level II, and 29.4% for level III. In recent years, Chengdu has been actively responding to the national call and starting to pay attention to air pollution. The air quality had been improved to some extent, but there was still a gap with the ideal air quality condition. Since the outbreak of COVID-19, Chengdu's air quality had always been at level I and II, and no serious pollution during the locking. It could show that when controlling air quality, we should pay attention to pollution source control measures to better improve air quality.
3.2.2. The Transverse Dimension of Space.

As for PM2.5 (figure 4) and PM10 (figure 5), it could be seen that the air quality of all regions at the during-blockade period in 2020 was generally better than that of the same period in 2019. The concentrations of PM2.5 and PM10 were significantly higher in the same period of 2019. According to statistical analysis, the average concentration of PM2.5 and PM10 at the during-lockdown period in 2020 was 42.2% and 53.2% lower than that of the same period in 2019, respectively. The average concentration of NO₂ and CO at the during-blockade period in 2020 decreased by 58.8% and 23.7%, respectively, compared with the same period in 2019.

![Figure 4. Comparison of PM2.5 in 2019 and 2020](image1.png)

![Figure 5. Comparison of PM2.5 in 2019 and 2020](image2.png)

4. Conclusion

Chengdu is an important development town in the western development. It is located in the Sichuan Basin and has poor air diffusion conditions. In recent years, the economy has developed rapidly and the air pollution caused by it has become increasingly serious. The lockdown measures taken since the discovery of the spread of COVID-19 has brought opportunities for reasonable explanation of the human impact on the environment. The results obtained through the paper from various angles shows that during the COVID-19 lockdown period, the concentration of various pollutants has decreased to varying degrees. In particular, the decreasing trend of the concentration of PM2.5 and PM10 is more obvious. Compared with other periods, the air quality has been greatly improved. In addition, the air quality level in Chengdu has been at level I and level II at the during-blockade period, and there is no pollution level. This is because a series of restrictive measures were taken at the during-blockade period. Therefore, we should reconsider the treatment of air pollution. We should pay attention to the control of pollution in the process of governance. All in all, this research can provide a useful supplement for air quality monitoring.

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