Temporal distribution, influencing factors and pollution sources of urban ambient air quality in Nanchong, China

Hong Zhou¹,², Youping Li¹†, Huifang Liu¹, Zhongyu Fan¹, Jie Xia³, Shanli Chen³, Yuxiang Zheng⁴, Xiaocui Chen⁵

¹College of Environmental Science and Engineering, China West Normal University, Nanchong 637009, China
²Sichuan Kaile Detection Technology Co., Ltd, Chengdu 611730, China
³Nanchong Environmental Monitoring Center, Nanchong 637000, China
⁴Guangzhou Research Institute of Environmental Protection, Guangzhou 510620, China
⁵The Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong, China

ABSTRACT

The PM₁₀, SO₂ and NO₂ mass concentrations were obtained over five years from monitoring stations across Nanchong, a southwest city in China. Changes in urban air quality over time, as well as the factors influencing that change, were evaluated based on air pollutant concentrations, the Air Pollution Index (API), and the Comprehensive Pollution Index (P). The results showed that the total annual mean PM₁₀, SO₂ and NO₂ concentrations over the five years studied were 61.1±1.1, 45.0±3.9 and 34.9±4.9 μg·m⁻³, respectively. The annual mean concentrations displayed a generally decreasing trend; lower than the annual mean second-level air quality limit. Meanwhile, the annual mean API values were in a small range of 52-53, the air quality levels were grade Ⅱ, and P values were 1.06-1.21 less than the slight level (P ≤ 1.31). Total monthly mean PM₁₀, SO₂, NO₂ concentrations, and API and P values were consistently higher in winter and spring than during autumn and summer. The results of a correlation analysis showed that temperature and pressure were the major meteorological factors influencing pollution levels. Pollution sources included industrial coal and straw burning, automobiles exhaust and road dust, fireworks, and dust storms.

Keywords: Air Pollution, Air Pollution Index, Comprehensive Pollution Index, Pollution Sources, Nanchong

1. Introduction

With rapid urbanization and industrialization, ambient air quality has worsened in many cities. This poor air quality is widely recognized as creating significant long-term and short-term risks, with impacts on human health, visibility, and climate change [1-4]. Air pollution results from complex interactions were caused by both natural processes and anthropogenic activities. Many studies apply pollutant concentrations, the Air Pollution Index (API), and the Comprehensive Pollution Index (P) to evaluate urban air quality. Kyrkilis, et al. [5] developed the “gathering air quality index” results showed that this evaluation method can effectively reveal the health effects of pollution. Cairncross, et al. [6] applied an API system to monitor ambient pollutant concentration data for the city of Cape Town, South Africa. The results indicated that short-term exposure to common air pollutants, including particulate matter (PM₁₀, PM₂.₅), sulfur dioxide, ozone, nitrogen dioxide and carbon monoxide was associated with increased daily mortality. Zhou et al. [7] evaluated ambient air quality based on API in Guangzhou, China, finding that TSP was the dominant pollutant in ambient air. TSP, SO₂ and NO₂ contributions were approximately 62%, 12.3% and 6.4%, respectively. In addition, Xiong et al. [8] and Li et al. [9] applied the CPI to evaluate the changing trends of urban air quality in China.

A literature survey shows that studies of urban air quality in China have mostly concentrated on metropolis areas, such as Beijing, Guangzhou and Wuhan [7,10,11]. There are fewer studies about urban ambient air quality in medium cities. With rapid development in these areas, however, the urban air quality problem is becoming increasingly serious. This study focuses on one of these medium-sized cities, Nanchong, which is located in the Chengdu-Chongqing Economic Zone (CCEZ), a zone in southwest China. This study examined mass concentrations, API, and P values to evaluate the temporal distribution of air quality, and applied
a correlation analysis to assess influencing factors based on hourly changes in air pollutant concentrations (PM10, SO2 and NO2) in Nanchong. Results are intended to inform environmental management approaches and air pollution prevention.

2. Materials and Methods

2.1. Study Area

Nanchong, located in the northeast of the Sichuan province and north of the CCEZ, encompasses an area of 101 km² (30.6°-31.9°N, 105.5°-107°E). It falls within a subtropical humid monsoon climate, with an annual average temperature of 17 °C and annual average precipitation of 1100 mm. The four seasons are distinctive, with a prevailing northwest wind. In 2013, the population was 1.06 million and there were 700,000 motor vehicles (http://www.nanchong.gov.cn/).

2.2. Data Sources and Method

The hourly PM10, SO2 and NO2 mass concentration data were collected using an online air pollutant monitoring system at five monitoring stations across the city, identified as Jiance (JC), Lianyou (LY), Shiwei (SW), Gaoping (GP) and Jialing (JL). Data were collected with an online air pollutant monitoring system at five monitoring stations between January 2008 and December 2012 (Fig. 1). The mathematical average of data from the five monitoring stations was calculated to represent Nanchong as a whole. The hourly, daily and monthly average concentrations were calculated using the following equations:

\[
C_{dhy} = \frac{\sum_{i=1}^{5} C_i}{5} \quad (1)
\]

\[
C_{dhy} = \frac{\sum_{i=1}^{n} C_{ihy}}{n} \quad (2)
\]

\[
C_{mby} = \frac{\sum_{i=1}^{m} C_{ihy}}{m} \quad (3)
\]

In these equations, the \( C_{dhy} \), \( C_{dhy} \) and \( C_{mby} \) are hourly, daily, monthly average concentrations of the pollutants; \( C_i \) is the hourly concentration at each station; and \( n \) and \( m \) are the effective information in a discrete day and month.

Quality assurance (QA) and quality control (QC) procedures were conducted throughout the sampling period, including regular instrument calibration with Standard Reference Materials (SRM). The data were stored in the Urban Environmental Information System of Nanchong Environmental Protection Bureau as 5 minute-average values, following a quality check [12]. SO2 was measured using a UV fluorescence method analyzer (Thermo Electron Corporation Model 43i; Thermo Fisher Scientific, US); NO2 was measured using a Dual-channel chemiluminescence analyzer (Thermo Electron Corporation Model 42i; Thermo Fisher Scientific, US); and PM10 was measured using a β-Ray attenuation analyzer (Thermo Anderson FH 62 C14 Series; Thermo Fisher Scientific, US). The detection limit was the same across all the three analyzers, at 1 μg·m⁻³.

API values, based on the mass concentrations of all pollutants, are better for assessing air quality than the EPA’s pollutant standards index (PSI) [13]. Daily API is calculated using the following equations:

\[
I_i = \frac{I_{\text{max}} - I_{\text{min}}}{C_{\text{max}} - C_{\text{min}}} \left( C_i - C_{\text{min}} \right) + I_{\text{min}} \quad (4)
\]

\[
API = \max (I_1, I_2, \ldots, I_n) \quad (5)
\]

In these equations, \( I_i \) is an air pollutant index; \( C_i \) is the daily concentration of pollutants; \( C_{\text{max}} \) and \( C_{\text{min}} \) are the two values closest to \( C_i \); \( I_{\text{max}} \) and \( I_{\text{min}} \) are the two values close to \( I_i \); and \( I_{\text{max}} \) and \( I_{\text{min}} \) are held as integers. Finally, \( I_{\text{max}} \), which represents the air pollution index, is used to represent the primary pollutant in the city.

Primary pollutants are not reported to the public if the API value is below 50. The API ranges and relevant air quality grades are: I (0~50), II (51~100), III (101~150), IV (151~200), V1 (201~250), V2 (251~300), V (300~600)[7].

The Comprehensive Pollution Index reflects and evaluates air quality. It is a dimensionless index, based on environmental quality standards and pollutant concentration. P quantitatively describes environmental pollution, and it is used to evaluate the air quality situation as a whole. P is calculated using the following equations:

\[
P = \sum_{i} P_i \quad (6)
\]

\[
P_i = C_i / S_i \quad (7)
\]

The load coefficient of the air pollutant was calculated using the following equation:

\[
F_i = P_i / P \quad (8)
\]

In these equations, \( P \) is the Comprehensive Pollution Index; \( P_i \) is the pollution index of a discrete pollutant; \( S_i \) is the secondary standard limit level and \( F_i \) is the load coefficient of the air pollutant. Table 1 shows the Comprehensive Pollution Index classification standard.

Surveys show that air quality is frequently evaluated using statistical methodologies [14-17]. In this paper, correlation analysis in SPSS (17.0) was applied to analyze the temporal distribution of urban ambient air quality in Nanchong.

<table>
<thead>
<tr>
<th>Pollution state</th>
<th>Moderate</th>
<th>Slight</th>
<th>Unhealthy</th>
<th>Very unhealthy</th>
<th>Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>≤ 1.3</td>
<td>1.31-4.00</td>
<td>4.01-8.00</td>
<td>8.01-12.00</td>
<td>&gt; 12.00</td>
</tr>
</tbody>
</table>
3. Results and Discussion

3.1. Temporal Distribution of Air Quality

3.1.1. Annual variation in air quality

The total annual mean concentrations for PM$_{10}$, SO$_2$ and NO$_2$ were 61.1±1.1, 45.0±3.9 and 34.9±4.9 μg·m$^{-3}$, respectively, during the study period. Fig. 2 shows the variation in trends over time. The annual mean concentrations of PM$_{10}$ decreased slightly over time, the maximum value was 62.8 μg·m$^{-3}$ in 2008. The SO$_2$ concentrations also generally followed a downward trend, with the exception of a jump to 51.9 μg·m$^{-3}$ in 2011. This jump may be due to isolated air pollution episodes, such as a pollution event at an oil refinery. NO$_2$ concentrations declined from 42.0 to 29.0 μg·m$^{-3}$ between 2008 and 2011. The results showed that the annual mean PM$_{10}$, SO$_2$ and NO$_2$ concentrations were less than the second-level air quality limit (100, 60 and 40 μg·m$^{-3}$ for PM$_{10}$, SO$_2$ and NO$_2$ respectively) issued by Ministry of Environmental Protection of China, with the exception of NO$_2$ in 2008 (42.0 μg·m$^{-3}$). Nevertheless, based on statistical days, during the 5 years studied, PM$_{10}$ concentrations exceeded the daily mean second-level limit (150 μg·m$^{-3}$) on 8 days, and NO$_2$ concentrations exceeded the second-level limit (80 μg·m$^{-3}$) on 7 days.

The annual variations seen for Nanchong were similar to cities reported by Li et al. [18]. The mean PM$_{10}$ concentrations were lower than megacities in mainland China such as Beijing (122.0 μg·m$^{-3}$), Shanghai (88.0 μg·m$^{-3}$), Guangzhou (72.0 μg·m$^{-3}$) and Chengdu (115.0 μg·m$^{-3}$), but concentrations were higher than cities and/or countries outside China, such as Tokyo (24.0 μg·m$^{-3}$) and Ireland (40 μg·m$^{-3}$). Nonchong NO$_2$ concentrations were higher than in Tokyo (5.0 μg·m$^{-3}$) and Europe (4.0 μg·m$^{-3}$). These results suggest that the air quality in Nanchong is of a higher quality overall than in the megacities in mainland China. This can likely be attributed to government actions that have strengthened the management and monitoring of vehicle emissions, changed the energy structure, and improved the gasification rates and clean production processes.

The annual API values from 2008 to 2012 ranged from 52-53 in Nanchong (Table 2), which were lower than Beijing (84), Guangzhou (57), Shanghai (63), Chongqing (74) and Chengdu (80) (http://datacenter.mep.gov.cn/). In addition, 47.9% (175) of the total days in 2009 had a recorded air quality at level Ⅰ (0 < API ≤ 50); there were more than 50% of total days that were at level Ⅱ (50 < API ≤ 100). A total of 15 days exceeded Ⅲ (100 < API ≤ 200) in the five years. PM$_{10}$ was the primary pollutant for 242 days in 2012, followed by 222 days in 2010. PM$_{10}$ was the primary pollutant on only 134 days in 2009, with ranges from 37-66%. SO$_2$ was the primary pollutant on 7-22% of the total days. NO$_2$ did not appear as a primary pollutant, and was the pollutant with the highest levels on only 4 days in 2009. Over the course of the five years, 20-48% of the total days had no primary pollutants; 30% of these days occurred in 2009. The API values indicate that PM$_{10}$ and SO$_2$ were the main contributors to Nanchong air pollution.

The P values ranged from 1.06-1.21, lower than the “slight” level (P ≤ 1.31) (Table 3). The pollution loading percentage revealed that NO$_2$ was the primary pollutant in 2008 (41.8%), 2009 (40.4%)
and 2012 (37.1%). However, PM$_{10}$ was the primary pollutant in 2010 (38.6%) and 2011 (35.8%). The loading percentage of SO$_2$ was 23.2%-31.6%, lower than PM$_{10}$ and NO$_2$. The pollution loading percentages point to NO$_2$ as the primary pollutant in Nanchong, followed by PM$_{10}$.

Study results indicated that the three evaluation methods resulted in significant differences in determining primary pollutants. The API showed that PM$_{10}$ and SO$_2$ were the main contributors to air pollution; when P was used as the indicator, NO$_2$ was the major pollutant, followed by PM$_{10}$.

3.1.2. Monthly variation of air

Fig. 3(a) shows the total monthly and seasonal mean concentration variations of PM$_{10}$, SO$_2$ and NO$_2$. The highest pollutant concentrations were seen in winter, followed by spring, autumn and summer. The PM$_{10}$, SO$_2$ and NO$_2$ concentrations were 50.8-78.6, 32.0-59.8 and 28.1-39.7 $\mu$g·m$^{-3}$ from January to December, respectively; these ranges are less than the annual mean second-level limitation. However, SO$_2$ exceeded the limit during 9 months (mainly in winter each year), and NO$_2$ exceeded the limit during 12 months (spring and winter), of the total 60 months studied. The PM$_{10}$ monthly concentrations were lower than the limit during these months. In addition, there were significant fluctuations in the monthly mean API and P values from 2008 to 2012 (Fig. 3(b)). The monthly mean API value was 53; the highest API value was 63, in January; and the minimum API was 47, in August. These values fall into air quality levels Ⅰ and Ⅱ.

Compared to other megacities in mainland China, the monthly mean API values in Nanchong were lower than Shanghai (63), Guangzhou (47), Chengdu (74) and Wuhan (76). The monthly P values were 0.93-1.39; the maximum (1.39 < 4.00, Slight) P values were seen in January and December; and the minimum P values (0.93 < 1.31, Moderate) were seen in August.

Overall, the monthly variations in air quality resulted in similar patterns across the three evaluation methodologies; the summer and autumn index values were lower than in spring and winter.

3.2. Influencing Factors

Table 4 provides the results of the correlation analysis, used to determine possible relationships between the pollutants (PM$_{10}$, SO$_2$ and NO$_2$) and meteorological factors (temperature, pressure, precipitation and wind speed) (http://www.wunderground.com/). There were a number of specific correlations worth discussing. First, temperature was negatively correlated with PM$_{10}$, SO$_2$ and NO$_2$ (R= -0.587, -0.677, -0.452, p < 0.001). This may be due to the fact that the vertical diffusion of air pollutants mainly depends on temperature [19]. The atmosphere is unstable when the temperature is high. As such, pollutants diffuse upwards under thermal convection, resulting in lower pollutant concentrations.

Pressure was positively correlated with the pollutants (PM$_{10}$, SO$_2$ and NO$_2$) (R= 0.501, 0.623, 0.384, p < 0.001). The atmosphere is unstable when controlled by a low pressure air parcel, allowing the air pollutants close to the ground to rise to a higher altitude, and supporting pollutant diffusion and dilution by rain. Precipitation was negatively correlated with PM$_{10}$, SO$_2$ and NO$_2$ (R= -0.373, -0.578, -0.224, p < 0.001). Precipitation has a flushing action on air pollutants in the air; air pollutants and water droplets...
Table 4. Correlation Analysis between PM$_{10}$, SO$_2$, NO$_2$ and Meteorological Elements

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Pressure</th>
<th>Wind speed</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{10}$</td>
<td>-0.587**</td>
<td>0.501**</td>
<td>-0.246</td>
<td>-0.373**</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>-0.677**</td>
<td>0.623**</td>
<td>0.000</td>
<td>-0.578**</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>-0.452**</td>
<td>0.384**</td>
<td>-0.506**</td>
<td>-0.224</td>
</tr>
</tbody>
</table>

**Correlation is significant at the 0.01 level (2-tailed).**

collide with each other during the precipitation process. Particulates in the air can be captured, and some of the pollution gases dissolve in water [20]. Nanchong experiences a normal distribution of rainfall volume, with higher rain/storms from May to September [21]. As such, ambient air pollutants are dispersed and diluted by frequent rainfall. The wind speed has dual effects on pollutant concentrations. Within a certain range (wind scale < 4), the wind speed favors air pollutant diffusion and dilution. When that range is exceeded, the increased wind speed can lead to significantly increased PM$_{10}$ concentrations [22]. In Nanchong, the boundary layer was lower, the temperature was higher, and the rainfall was abundant during the summer and autumn. As a result, pollutant concentrations were higher in the spring and winter.

3.3. Pollution Sources

3.3.1. Coal combustion, automobiles and road dust

The studies have shown that the main sources of urban air pollution are coal combustion and automobile exhaust [23-24]. Nanchong is one of three large petrochemical industry bases in Sichuan province, and coal consumption by industry is an important source of air pollution. Due to poor production technology and management, coal utilization is lower. Data collected during the study period indicate that the oil refinery near LY station emitted air pollutants, including NO$_X$ and SO$_2$, etc [25].

![Fig. 4. Monthly mean PM$_{10}$, SO$_2$ and NO$_2$ concentrations.](image)

Fig. 4 shows the statistical distribution of pollutant concentrations at the five stations from 2008 to 2012. The monthly mean SO$_2$ concentrations at the five stations ranged from 32.3 μg·m$^{-3}$ at SW to 48.7 μg·m$^{-3}$ at LY; NO$_2$ concentrations ranged from 23.6 μg·m$^{-3}$ at SW to 48.8 μg·m$^{-3}$ at LY. Results indicate that SO$_2$ and NO$_2$ concentrations in the industrial area covered by LY were clearly higher than in the non-industry region station (SW).

Vehicles and road dust are also important sources of urban air pollution in Nanchong. The number of motor vehicles has been increasing over the past several years, and some illegally-operated vehicles falling short of the emission standard may enter the city center. These sources are responsible for the higher PM$_{10}$. For example, the SW measurement station is located in a commercial and shopping center, where there is significantly more traffic on working days. The monthly PM$_{10}$ concentrations at this station were higher than the other stations, and there were 3 months (103.6, 101.2 and 100.6 μg·m$^{-3}$) when the mean second-level limit was exceeded.

3.3.2. Biomass burning

Agriculture crop residue burning is an important source of atmospheric pollution, [26-27] with burning activities occurring during summer harvest time [28]. Nanchong has 200,000 hectares for growing activities, and crop straws are often burned in the open field during summer harvest time. The resulting air pollutants are dispersed directly into the urban atmosphere. Fig. 5 shows PM$_{10}$ concentration variations in June (when there are burning activities) and August (when there are no burning activities). The highest concentration in June was 72.6 μg·m$^{-3}$, and 93.3% of the days during this period exceeded the daily mean first-level limit.

![Fig. 5. PM$_{10}$ concentrations during biomass burning activity and no activity.](image)
(50 μg·m\(^{-3}\)). In August, however, the highest concentration was 61.8 μg·m\(^{-3}\), and a lower proportion of the days, 60%, exceeded the limit. This leads to the conclusion that PM\(_{10}\) concentrations affected by burning activities in June were high during the five years studied.

### 3.3.3. Celebration activities

In this study, fireworks displays were identified as the most unusual source of pollution, and as one with significant impacts. These pollution episodes appear responsible for high concentrations of particles (especially metals and organic compounds) and gases [29-32]. For example, the Spring Festival Holiday, which often includes fireworks, was celebrated on January 25-26, 2009; February 13-14, 2010; February 2-3, 2011; and January 22-23, 2012.

Fig. 6 illustrates that PM\(_{10}\) and SO\(_2\) concentrations increased instantaneously during firework display periods from 23:00 (late night) to 02:00 (early morning). For example, PM\(_{10}\) concentrations between 01:00-03:00 on the early morning of February 3, 2011 (276.0-321.3 μg·m\(^{-3}\)) were significantly higher than the daily mean third-level (250 μg·m\(^{-3}\)); concentrations at 00:00-23:00 (166.0-174.8 μg·m\(^{-3}\)) and 04:00-06:00 (173.3-228.8 μg·m\(^{-3}\)) exceed the second-level limit. In addition, the maximum SO\(_2\) concentrations always appeared at 00:00 on those days in those years. This demonstrates the significance of these events on air pollution in Nanchong.

### 3.3.4. Long range transport dust

Dust storms are an example of a severe weather event, with potential long-term, harmful effects. In China, these dust storms can destroy atmospheric and ecological environments in arid and semiarid regions [33], and can even travel across the Pacific Ocean and reach the western coast of North America [34]. The dust storms impacting the study area come from the Gobi Desert, within Mongolia and northern China, and the Taklimakan Desert in western China [35].

In past years, Beijing and Chengdu have been affected by dust storms [3, 36], and although Nanchong is far from north China, its air quality can be influenced by dust storms under certain conditions. For example, in April 2009, Nanchong’s air quality was significantly affected by dust from the north [37]. Air mass
backward trajectories arrived at 500, 1,000 and 1,500 m above ground level on April 24-26, 2009 (over 72 hours), as calculated by the NOAA HYSLIMIT 4 trajectory model (Fig. 7). In this case, dust from the western part of Mongolia moved along the northern boundary of Inner Mongolia and passed through Gansu province, before reaching the Nanchong monitoring sites. Soil dust was transported to Nanchong by northerly airflow as well, causing PM$_{10}$ to rapidly rise. The maximum hourly concentration was 281.4 μg·m$^{-3}$ on April 24, exceeding the daily mean third-level; 196.2 μg·m$^{-3}$ on April 25, exceeding the daily mean second-level; and 132.0 μg·m$^{-3}$ on April 26. In this case, a remote source caused high pollutant concentrations, impacting local air quality.

4. Conclusions

This study evaluated the temporal distribution of air quality measures, using three methods: mass concentrations, API, and P values. These data were used to identify the factors that influenced air quality the most in Nanchong from 2008 to 2012. The major findings can be drawn as follows.

The total annual mean PM$_{10}$, SO$_2$ and NO$_2$ concentrations were 61.1±1.1, 45.0±3.9 and 34.9±4.9 μg·m$^{-3}$, respectively. The annual mean concentrations of PM$_{10}$, SO$_2$ and NO$_2$ were less than mean second-level air quality limit; the only exception was the NO$_2$ concentration in 2008, which reached 42.0 μg·m$^{-3}$. Annual API values were 52 to 53. During the study period, API values were lower than I (≤50) on 583 days, and exceeded III (100 < API ≤ 200) on 15 days. PM$_{10}$ was the main contributor to air pollution, followed by SO$_2$ and NO$_2$. Annual mean P values were 1.06-1.21, which are lower than slight levels (P ≤ 1.31) and the air quality was classified as “good” in Nanchong.

There were clear differences in mean PM$_{10}$, SO$_2$ and NO$_2$ concentrations by month and season. The concentrations were higher in spring and winter than in summer and autumn. The PM$_{10}$, SO$_2$ and NO$_2$ concentrations were 50.8-78.6, 32.0-59.8 and 28.1-39.7 μg·m$^{-3}$ from January to December, respectively. This is less than the annual mean second-level limit. The monthly mean API value was 53; the highest API value was 63 in January and the minimum API value was 47 in August. Air quality levels fell into the grades of I and II, and monthly P values were 0.93-1.39.

Many factors influence air pollution in Nanchong. First, the primary meteorological factors contributing to air pollution were temperature and pressure. Second, sources contributing to local pollution included industrial coal and straw burning, automotive exhaust, road dust and fireworks. Finally, dust storms generated higher PM$_{10}$ concentrations.

Nanchong currently experiences moderate air quality. To improve this quality, these study results suggest that the government should adjust the energy structure, develop clean energy technologies, adjust industrial layout, increase green areas, control emissions from motor vehicles, and improve road traffic conditions.

Acknowledgements

The work was supported by Scientific Research Fund of Sichuan Provincial Education Department (13ZB0011), Nanchong Science and Technology and Intellectual Property Bureau (13A0071), Chemical Synthesis and Pollution Control Key Laboratory of Sichuan Province (CSPC2014-4-2) and Science and Technology Department of Sichuan Province (2015)Y0094).

References

17. Shen JF, Feng JJ, Xie CL. Analysis of the spatial and temporal