



Spatiotemporal Variations and Possible Sources of Ambient PM₁₀ from 2003 to 2012 in Luzhou, China

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ABSTRACT

Descriptive statistics methods were used to study the spatiotemporal variations and sources of ambient particulate matter (PM₁₀) in Luzhou, China. The analyzed datasets were collected from four national air quality monitoring stations: Jiushi (S1), Xiaoshi (S2), Zhongshan (S3), Lantian (S4) over the period of 2003-2012. This city was subjected serious PM₁₀ pollution, and the long-term annual average PM₁₀ concentrations varied from 76 to 136 µg/m³. The maximum concentration was more than 3-fold of the annual average (40 µg/m³) issued by EPA-China for the ambient air quality. General temporal pattern was characterized by high concentrations in winter and low concentrations in summer, and general spatial gradient was in the reduction order of S2 > S4 > S3 > S1, which were both due to different particulate contributors and special meteorological conditions. The source apportionment indicated that vehicular emissions, road dusts, coal burning and chemical dusts were the major contributors of the identified PM₁₀ pollution, and the vehicular emissions and the road wear re-suspended particles dominated the heavy PM₁₀ pollution in recent years. Two other potential sources, agricultural and celebration activities could decrease the air quality in a short term. Finally, some corresponding suggestions and measures were provided to improve the air quality.

Keywords: Luzhou, Particulate matter pollution, PM₁₀ sources, spatiotemporal variations

1. Introduction

Atmospheric particulate matter (PM) is made up of solid and/or liquid particles, which enter the atmosphere through natural pathways or human activities. Numerous epidemiological studies, conducted over the past decades, have proved a strong association between ambient particulate matter and the mortality and morbidity of cardiovascular and pulmonary [1-3]. Among the particulate matter, PM₁₀ (diameter < 10 µm) had been widely getting global focus due to its various adverse environment and health effects [4-8]. Previous literatures have documented that the emission of PM₁₀ from China was much greater than that from other countries, not only for gaseous pollutants but also for primary particulate matter [9, 10]. High intensity emission of PM₁₀ has caused severe air quality problems in China, especially in cities [11]. According to the data from the World Bank in 2005, sixteen of the twenty-two most polluted cities in the world are located in China, and only 1% of all urban population in China lives in the cities with an annual average level of PM₁₀ below 40 µg/m³ (Table 1) issued by Environmental Protection Agency of China (EPA-China). Several investigations had also been carried out worldwide to study urban

atmospheric pollutants and to improve the air quality [12-14]. The PM_{2.5}, a fraction coming from the same sources of PM₁₀ in certain degrees [15, 16], is being on highlight nowadays in China. Most places, however, are still in the severe air pollution with PM₁₀ as principal pollutant. Studies on the variations and sources of PM₁₀, therefore, are in necessary and urgent for implementing some measures to tackle this issue.

Luzhou is located in the southeastern of Sichuan province, which belongs to the southwestern region of China. It is a trade center and a hub for transportation due to its favorable geographical location, being adjacent to Yunnan and Guizhou province. The Tuojiang River meets the Yangtze River, the third longest river around the world, in Luzhou where they divide this city into three parts: Longmatan, Jiangyang and Naxi region (Fig. 1(b)).

Table 1. PM₁₀ Concentrations in the Air Quality Standard Issued by EPA-China, 1996

Level of criterion	Annual (µg/m ³)	Daily (µg/m ³)
1 st	40	50
2 nd	100	150
3 rd	150	250



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With rapid economy growth in recent years, Luzhou is not only undergoing extreme urbanization, but also facing an increasing pressure regards to environmental protection and restoration of the ecosystem destroyed during those processes. Information published by EPA-China also indicates that it is suffering a worsening air quality for PM₁₀ concentration increasing in recent years. The days with PM₁₀ concentration larger than 50 $\mu\text{g}/\text{m}^3$, the first threshold for PM₁₀ daily concentration regulated in China ambient air quality standard, had been increasing from 2010 to 2012, and the time made up to 60.0%, 70.8% and 93.5% of each year [17], respectively. Furthermore, another new stringent air quality standard will be executed in 2016. Luzhou, therefore, is facing an extremely urgent environmental protection assignment.

The study of particulate matter in Luzhou relatively lags behind, and the source investigation of particles has never been conducted here. It is dramatically essential and urgent to study the spatio-temporal variations and sources of PM₁₀ for offering some advantageous measures to improve the air quality. We performed this work first to tackle those problems mentioned above by analyzing the intensive data collected from four air quality monitoring stations from 2003 to 2012. Besides, we also aimed to assess the air quality objectively and quantitatively.

2. Materials and Methods

2.1. Study Area

Luzhou (105°09'-106°28'E, 27°39'-29°20'N), a mountainous urban located in the southeastern of Sichuan basin (Fig. 1(a)), is the area studied. It has an area of 71.88 km² with about 0.78 million inhabitants. The climate of here belongs to the typical basin and subtropical climate, that is, sufficient sunshine, abundant rainfall and high annual average air temperature. Summers are usually hot with thunderstorm weather, while winters are typical moist with light fog. The annual average temperature and wind velocity

in this city is 17.5–18.0°C and 0–2 m/sec, respectively, and the strong wind seldom occurs here. *Yutang*, *Shibao gulf*, *Anning* and *Lantian* are four industrial areas built decades ago in this city, and they were the important chemical industry bases before 1990s in China. To date, chemical industry is one of the major industries for Luzhou municipality. According to the statistical information announced by Luzhou municipal bureau of statistics, the number of motorized vehicles in this city had soared to 329,000 in 2010 with the economy increasing sharply over recent years, which of them were more than 94,600 cars and 233,900 motorcycles.

2.2. Sampling Sites and Database

The study period covers ten years, from 2003 to 2012, and the PM₁₀ dataset was collected from Environmental Protection Bureau of Luzhou (LEPB). A well-organized air quality monitoring network was built and operated normally from 1990s by LEPB for understanding and predicting the present and future status of the air quality. The monitoring network is composed of four monitoring stations: *Jiushi* (S1, a scenic spot acting as urban background site), *Xiaoshi* (S2, a dock and commercial center of this city), *Zhongshan* (S3, an urban traffic site), *Lantian* (S4, an urban fringe near chemical industries) (Fig. 1(b)). Monitoring systems were all placed at a height of 17 m above the ground, and there were not any high buildings or plants influencing the sampling processes. At each station, real-time monitoring campaign was carried out by a PM₁₀ main flow sampler (1,000 L/min) equipped with glass fiber filters and analyzed by the beta ray attenuation method (MP101M; Environemt SA, USA), and the whole real-time monitored area by the stations (21 km²) accounts for 29.2 percentages of the total area (71.88 km²). The accuracy of each monitoring system was calibrated with beta ray attenuation method, and the results of correction are shown in the Table 2.

In this work, all statistics and regression models, finished with ORIGIN Version 9.0 (OriginLab Corp., USA) software, were established for identifying variation patterns and sources of PM₁₀.

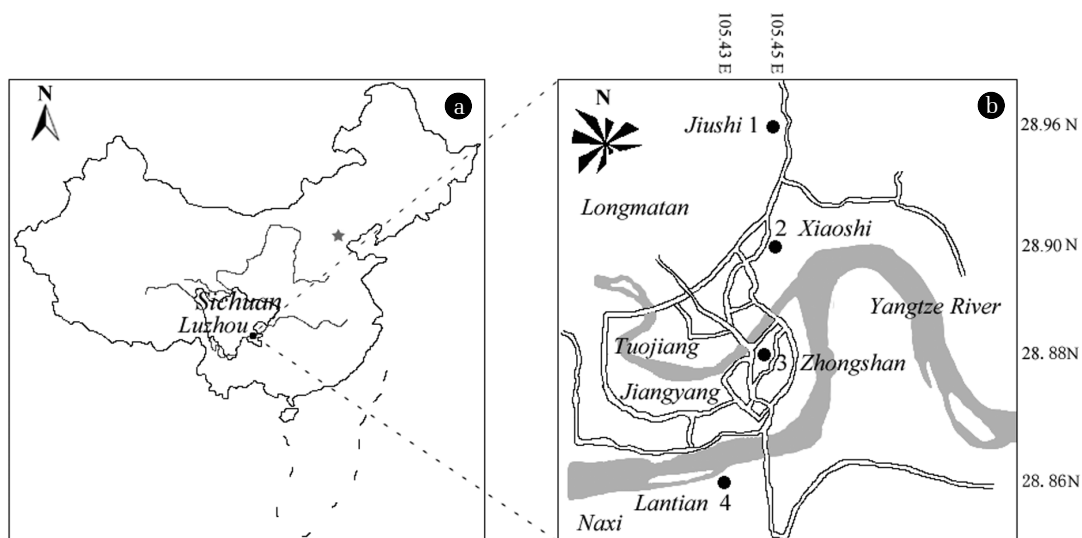


Fig. 1. Luzhou (a) geography position and (b) monitoring stations of PM₁₀.

Table 2. The Correcting Result of Beta Ray Diffractometer MP101M Monitoring System

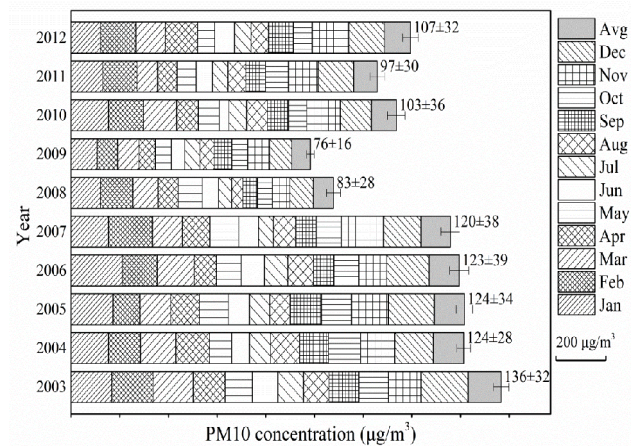
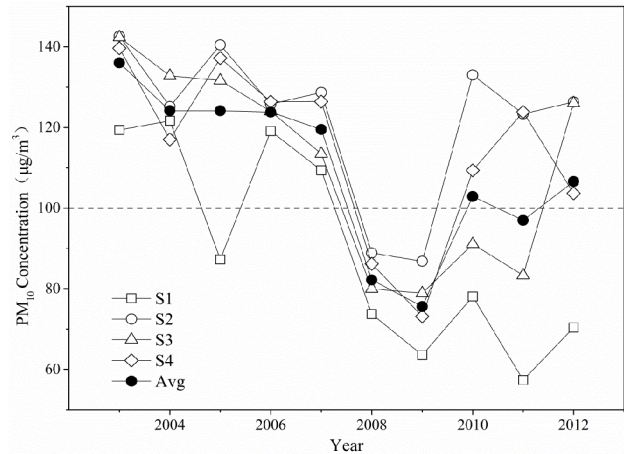
Monitoring station	Jiushi ($\mu\text{g}/\text{cm}^2$)	Xiaoshi ($\mu\text{g}/\text{cm}^2$)	Zhongshan ($\mu\text{g}/\text{cm}^2$)	Lantian ($\mu\text{g}/\text{cm}^2$)	
Theoretical value	686.5	1.800	686.5	1.800	
Jan	657.8	1.805	696.3	1.796	
Feb	675.6	1.810	696.3	1.800	
Mar	688.4	1.794	696.3	1.801	
Apr	692.6	1.799	696.3	1.805	
May	684.7	1.800	696.3	1.799	
Measured valve	Jun	679.6	1.790	696.3	1.796
Jul	654.3	1.806	696.3	1.807	
Aug	690.4	1.799	696.3	1.805	
Sep	688.7	1.800	696.3	1.801	
Oct	672.9	1.792	696.3	1.796	
Nov	679.2	1.798	696.3	1.805	
Dec	674.6	1.806	696.3	1.792	
Range of relative error (%)	-4.7 ~ +0.9	-0.6 ~ +0.6	-4.0 ~ +1.4	-0.4 ~ +0.4	

3. Results and Discussion

3.1. Variations of PM_{10} Concentration

3.1.1. Temporal Variations

For analyzing temporal variations, seasonal and annual PM_{10} mean concentrations of Luzhou were calculated based on the 24-hr average of PM_{10} concentrations over a 10-yr period from January 1, 2003 to December 31, 2012. The long-term annual PM_{10} mean concentrations varied in the range of 76–136 $\mu\text{g}/\text{m}^3$ (Fig. 2). The upper threshold is more than 3-fold of the first level issued in China Ambient Air Quality Standard, which indicates the serious air pollution in Luzhou. According to the analysis, the air quality could only meet the third level most of the time over the 10 years, and only three years' air quality (2008, 2009 and 2011) could meet the second level criterion (Fig. 3). The air quality, furthermore, had been deteriorating again since 2010, which could be attributed to the increasing of automotive vehicles and the dramatic infrastructure construction during the recent years. These results were consistent with the work conducted by Qu and his co-workers in 2010, who studied the spatial distribution and interannual variations of PM_{10} over eighty-six Chinese cities. The results of their work indicated that in the middle latitudinal zone, high PM_{10} (119–147 $\mu\text{g}/\text{m}^3$) occurred at Chongqing-Chengdu-Luzhou [14]. Compared with other metropolises located in East Asia, the atmospheric particle concentrations observed in Luzhou were also much higher. For example, the mean PM_{10} concentrations were about $63.2 \pm 17.9 \mu\text{g}/\text{m}^3$ in Seoul between 1996 and 2010 [18], $55.3 \mu\text{g}/\text{m}^3$ in Hongkong between 1990 and 1994 [19], and $56.7\text{--}67.6 \mu\text{g}/\text{m}^3$ in Pearl River Delta region between 2006 and 2009 [20]. It is worth to note that the air quality has been improved since 2008 due to systematic air protection measures issued by government and carried out by industries. For example, many small-scale coal steam-electric plants were closed and chemical plants were equip

**Fig. 2.** Yearly and monthly PM_{10} average concentrations from 2003 to 2012.**Fig. 3.** Annual average PM_{10} concentrations of S1, S2, S3, S4 and the city from 2003 to 2012.

* Dash line: the 2nd level ($100 \mu\text{g}/\text{m}^3$) of the China ambient air quality standard for annual average values.

ped with dust control units. That also can responsible for the annual average concentration of PM_{10} decreased to the lowest ($76 \mu\text{g}/\text{m}^3$) in 2009.

Descriptive statistics for seasonal variations of PM_{10} mean concentrations were summarized and displayed in the Fig. 4. Seasonal mean PM_{10} concentrations of the study period were 104 ± 17 , 76 ± 12 , 53 ± 6 and $71 \pm 10 \mu\text{g}/\text{m}^3$ for winter, spring, summer and autumn, respectively. Seasonal variation was generally characterized that PM_{10} concentrations varied in a narrow range of $40\text{--}60 \mu\text{g}/\text{m}^3$ during the summertime and varied in a relative wide range of $80\text{--}130 \mu\text{g}/\text{m}^3$ during the wintertime. As the Fig. 2 indicates the lowest and highest PM_{10} concentration of each year always appeared in summer and winter, respectively. The detail information on the monthly average PM_{10} concentrations was also displayed in the Fig. 2, and it varied in a wide range of $39\text{--}210 \mu\text{g}/\text{m}^3$. The formation of seasonal concentration gradients was primarily due to the variation of emission sources and metrological conditions.

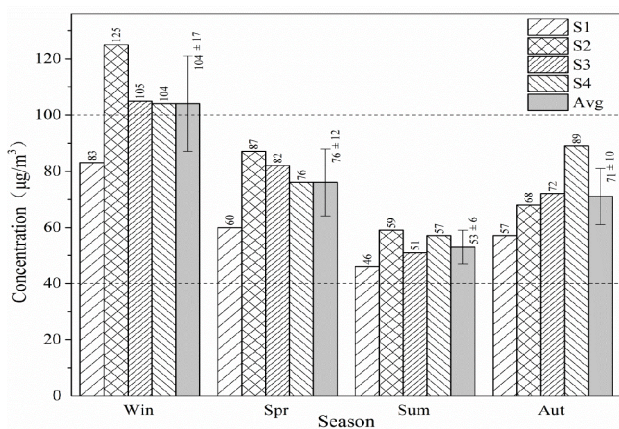


Fig. 4. Seasonal average PM₁₀ concentrations variations of S1, S2, S3, S4 and the city from 2003 to 2012.

* Dash lines: 1st and the 2nd level (100 µg/m³) of the China ambient air quality standard for annual average values, respectively.

Generally, concentrations are lower in summer for several possible reasons: i) lower vehicle exhaust emissions occur due to higher burning efficiency or possibly decreased traffic volume, ii) smaller coal-, gas- and wood-materials was burnt for residential heating, iii) higher velocity and humidity during the summertime decrease the potential formation of new particles through photochemical reactions, iv) there is generally more efficient dilution due to more intense air turbulent mixing and higher temperature. Contrarily, more emissions and adverse meteorological conditions for dispersing might contribute to the higher PM₁₀ concentration in the wintertime. The air quality of the seasons, except for winter, could satisfy the second level criterion. However, the PM₁₀ concentrations were always larger than the third threshold (100 µg/m³) of the air quality standard in the wintertime. In a word, this city was subjected more serious PM₁₀ contamination due to its rapid urbanization when compared with the cities sharing similar meteorological and topographic conditions [21, 22]. The PM₁₀ sources apportionment study seems to be more necessary and urgent because the bad air quality might cause some healthy and environmental problems. Some effective measures, therefore, should be taken to inhibit the worsening trend of ambient air quality.

3.1.2. Spatial Variations

Interesting information about the spatial PM₁₀ concentration distribution in Luzhou was obtained by analyzing the data collected in different sites. Using one-way ANOVA procedure on the long term mean PM₁₀ concentrations of different monitoring sites, the concentrations were found to be different from each other significantly (0.95 confidence level). Universal negative correlation between the concentrations and the distance of sites away from the city center, however, were not found in our research through Pearson correlation analysis, which is due to the concentrations affected progressively by the local sources and the adverse meteorological conditions.

The Fig. 3 clearly depicts the 10-yr spatial variations that the average concentrations of four monitoring sites were in the reduction order: S2 > S4 > S3 > S1. Formation of this spatial gradient

could be attributed to different point sources in different regions. The air quality of S2 was dramatically affected by the activities of commercial activities and the emissions from vehicles, which always use diesel oil as energy, especially the cargo ships [23-24]. S4 was not covered by the nature gas supplying system until 2012, and the coal was primarily used as energy source. The unpleasant ambient air quality in S4, on the one hand, might be the result of combustion fossil fuels. On the other hand, it might be affected by the discharge of chemical industry, which was identified as one of the main sources of particulate matters including PM₁₀ [20, 25]. The air quality of S3, located in the center of this city, was relative better than that of S2 and S4 due to fewer particles from industrial and commercial activities. S1 is located in the rural area possessing most green belt, and it was not directly affected by so much human activities like other places. Thus, S1 had the best air quality and was selected as the background reference, which could meet the second level of air quality standard over the whole study period.

According to the detailed information shown in the Fig. 3 and Fig. 4, spatial gradient may vary with time series. Compared with S1, the other three sites were all subjected particulate pollution in different degrees especially S2 and S4. During the winter, spring and summer, S2 suffered the worst air quality, which was due to its special regional function as commercial center. S4 was suffered more awful particulate pollution than S2 in autumn, which might be attributed to agricultural and industrial activities conducted here. In turn, these concentration differences in different sites precisely demonstrated the air quality was mainly controlled by anthropogenic sources, which were discussed in detail at the following sections.

3.2. PM₁₀ Sources Apportionment

Temporal and spatial variations of PM₁₀ concentration discussed in the previous sections clearly demonstrated high PM₁₀ pollution concentrations were mainly linked to various kinds of anthropogenic activities. According to the history meteorological data, gale seldom happened in this city. Therefore, the effects of local sources on the PM₁₀ concentration in the ambient air were mainly discussed for sources apportionment in the following sections, and the effects of remote sources were neglected.

3.2.1. Coal Combustion

Coal burned by industries and residents was usually considered as the primary source of PM₁₀[24]. In view of the rapid economic development in recent years, most cities of China were polluted by complex emissions from different sources, which usually are coal combustion and vehicular emission [26, 27]. The coal combusted in China are usually containing higher sulfur than other countries due to no or insufficient desulfurization processes. In order to detect out the main sources, we analyzed the relationship between PM₁₀ and SO₂ over a short-term of 2008-2010, and the results of that is shown in the Fig. 5(a). Significant correlation relationship ($R^2_{Adj} = 0.560$) and the sensitive slope (0.668) between PM₁₀ and SO₂ concentrations indicates the two pollutants indeed come from the same sources. The coal combustion, therefore, plays key role in worsening the air quality. A more significant correlation

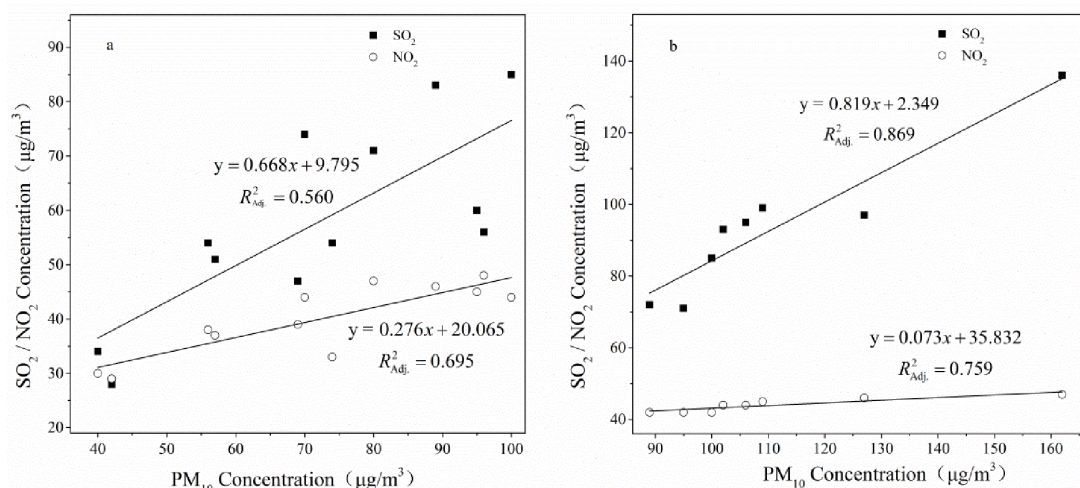


Fig. 5. Correlations between PM_{10} and SO_2 , NO_2 during (a) 2008-2010 and (b) the wintertime of 2008-2010.

coefficient ($R^2_{Adj} = 0.869$) and steep slope (0.819) between PM_{10} and SO_2 concentrations over the wintertime demonstrates that coal combustion contributes much more to the PM_{10} pollution during the winter (Fig. 5(b)). All the monitoring sites except S1 were suffered more serious PM_{10} pollution in the wintertime (Fig. 4) as the result of more coal and biomass burnt for industrial energy and residential heating. Another potential source contributed to the awful air quality over the wintertime was the smoking bacon tradition in this city, which can lead to the occurrence of PM_{10} alert concentration ($150 \mu\text{g}/\text{m}^3$) in a short term and contribute to the significant correlation coefficient between PM_{10} and SO_2 over the wintertime.

3.2.2. Traffic Source

Re-suspended road wear and particles exhausted by vehicles are often regarded as two other important contributors of PM_{10} [21, 28]. According to statistics data issued by the Luzhou government, the number of automobiles in this city dramatically increased to 329,000 in 2010 from 60,400 in 2008, which might contribute to the degradation of air quality. Cars without catalytic conversion systems usually discharge huge amount of gaseous pollutant and particles. Ketzler et al. also reported many new particles formation (nucleation) do not directly take place behind the tailpipes of the vehicles but in the ambient air [29]. Among the pollutants, NO_2 is a partially secondary pollutant formed by oxidation of NO emitted by automobiles, thus the slope of regressions cannot reflect the variation consistence between PM_{10} and NO_2 . The coefficients between PM_{10} and NO_2 , however, can act as the mark of the contribution of vehicles [30]. The coefficients between PM_{10} and NO_2 shown in Fig. 5(a) ($R^2_{Adj} = 0.695$) and 5(b) ($R^2_{Adj} = 0.759$) indicate a positive relationship between them, and suggests that PM_{10} and NO_2 might come from the same emission sources, vehicles.

Hourly variation information of PM_{10} concentrations at S3 was displayed in Fig. 6. S3 is located at traffic hot spots near Zhongshan Park, where has larger traffic volume than other three monitoring sites. Thus, PM_{10} concentration variations at this site can well and directly reflect the contribution of traffic to particulate pollution. Fig. 6 clearly shows the maximum PM_{10} concentrations

occurred during the daytime hours both in summer and winter when the traffic flow reached its peaks. As Johansson et al. pointed out the wetness of road surface is very important for PM_{10} re-suspending into ambient air [21]. Under the wet conditions, much less particles can be suspended into ambient air compared with the dry conditions, and other local factors, such as traffic volume, road roughness, air convection and road cleaning frequency can also affect the re-suspending of particles [31]. These peaks displayed in Fig. 6, thus, might be controlled by the emissions and re-suspended particles. Although the coefficient ($R^2_{Adj} = 0.869$) between PM_{10} and SO_2 is higher than that between PM_{10} and NO_2 ($R^2_{Adj} = 0.759$) during the wintertime, we still could draw out the conclusion that the particulate matter exhausted by the vehicles has become a key source controlling the PM_{10} concentration in the ambient air through comparing the long-term analyzing results Fig. 5(a) with Fig. 5(b).

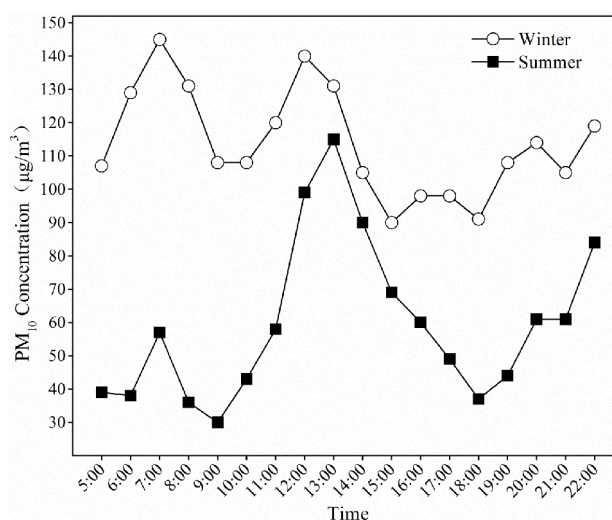


Fig. 6. Hourly PM_{10} concentrations at S3 on working days in summer and winter season.

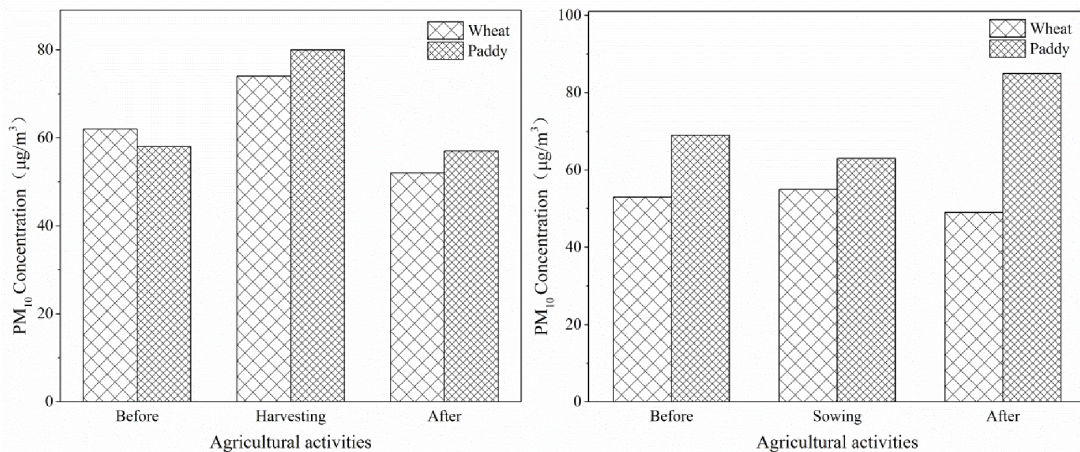


Fig. 7. Variations of PM_{10} concentrations at S4 during agricultural activities in 2009.

Table 3. Meteorology Conditions and PM_{10} Concentrations on January 25, 2008 and January 25, 2009

Occurring date	Weather	Daily PM_{10} concentrations ($\mu\text{g}/\text{m}^3$)	Daily wind speed (m/sec)	Daily wind direction	Daily temperature ($^{\circ}\text{C}$)	Daily relative humidity (%)
1/25/2008	Sunny	550	1.20	South	9	83
1/25/2009	Sunny	110	0.90	South	12	91

3.2.3. Agricultural Source

All the sites suffered more serious particulate pollution in autumn than that in summer could be clearly found in Fig. 4, and a sudden increase in PM_{10} concentration at S4 can also be clearly found. However, the spring and autumn in Luzhou is relative short, and their meteorological conditions are not significantly different from winter and summer, respectively. Thus, meteorological difference was not the primary contributor of the higher PM_{10} concentration in autumn. The possible agricultural sources around all sites were analyzed in order to explain the changes. S4 is located at the junction of urban and rural areas, which could be the best example to certify whether the agricultural activities contributed to the relative bad air quality in autumn or not. We studied the variations of periodical PM_{10} concentration when the sowing and harvest activities of wheat and rice, two main agronomic crops planted in Luzhou, were conducted. The periods studied as seeding were from October 11 to 20 and June 5 to 14 for wheat and paddy, respectively, and the harvest periods of them were from April 26 to May 15 and September 6 to 25, respectively.

Particle concentration variations over the sowing and harvest periods in 2009 are shown in the Fig. 7. It indicates the sowing activities of both agronomic crops almost have no contributions to the PM_{10} concentration variations, while both the harvest activities of the two crops dramatically increased PM_{10} concentration. Particulate matters could be formed in the processes of cleaning corn and burning straw. Similar analysis, resembling the one presented here, of other three sites should be carefully performed due to the different functions of different regions. Meanwhile, similar studies carried out in other urban areas might bring a better understand of this airborne particle source [32, 33].

3.2.4. Fireworks Source

In order to analyze other potential sources of PM_{10} , we took the

eve of Spring Festival in 2009 and the corresponding time in 2008 as the study period and S4 as the study area. Table 3 provides the meteorological conditions of the two periods, and the analysis results of hourly PM_{10} variations are shown in the Fig. 8. We could see the PM_{10} concentration peak on January 25-26, 2009 precisely happened during the fireworks display period, and the higher concentrations persisted for several hours with adverse dispersing meteorological conditions, such as the lower wind speed and humidity. According to the regulations, fireworks displays were in legal during the Spring Festival Holiday (from January 23 to February 9, 2009) in this city, and it was subjected awful air quality most of this period. However, no similar variation trend occurred over the same period in 2008, which demonstrates the

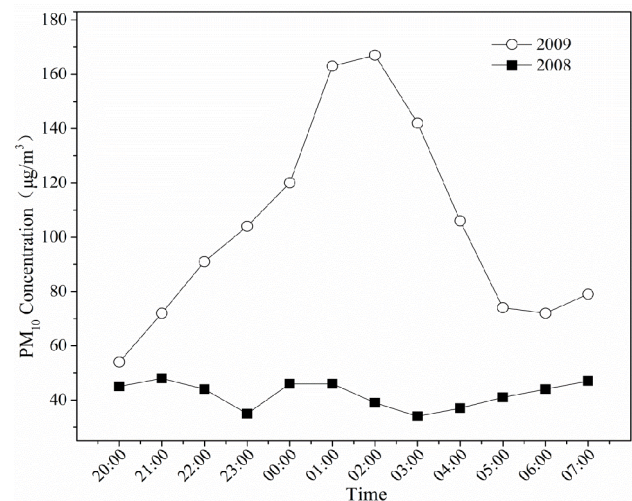


Fig. 8. Hourly PM_{10} concentrations at S4 during January 25-26 in 2008 and 2009.

firework displays and other celebrations indeed are contributors to the particulate pollution, and they can deteriorate the air quality in a short-term. The same results could also be obtained by comparing other celebration periods with the periods without fireworks display.

4. Conclusions

This work studied the PM₁₀ concentration variation profiles and its sources through analyzing the data collected from four different monitoring stations established in Luzhou city from January 2003 to December 2012. Generally, a number of interesting observations can be derived from the findings:

- The range of the long-term annual, seasonal, and monthly PM₁₀ mean concentrations over the period 2003-2012 ranged from 76 to 136, 53 to 104, and 39 to 210 µg/m³, respectively. Time series of PM₁₀ concentration discussed in our paper demonstrated this city was suffered serious PM₁₀ pollution, and the air quality in Luzhou had been deteriorating again from 2010. The heavy PM₁₀ pollution was more serious during winter and springtime. However, the air quality was much better in recent years than that before 2008.
- Spatial PM₁₀ contamination varied in the order of S2 > S4 > S3 > S1, and S1 could meet the second level in air quality standard issued by EPA-China all the time. While the other three areas could only be complacent about the third level. On the one hand, the formation of spatial concentration gradient could be the result of different point sources in different functional regions. On the other hand, the special topographical conditions (basin) and metrological conditions, such as air wetness, wind speed, atmospheric pressure, and temperature also contributed to the formation of spatial concentration gradient.
- PM₁₀ sources apportionment demonstrated major sources in Luzhou were coal combustion, vehicular emissions and road wears, and chemical dusts. Among these pollution sources, the coal combustion was the primary source controlling the ambient PM₁₀ concentration. It is worth to note that the vehicular emissions and the road wear played an important role in contributing to heavy PM₁₀ pollution in recent years. Two other sources, agricultural and celebration activities can decrease the air quality in a short term.

Control and reduction particulate matter pollution is an urgent assignment that must be addressed in Luzhou city. Improving the air quality may be achieved through (1) connecting the households of this city to a central heating supply system which can greatly reduce the pollutants including PM₁₀ that originates from private use of fossil fuels for domestic heating, (2) promoting the efficiency of industrial and residential coal burning, (3) taking advantage of natural gas instead of gasoline and coal as fuel in view of the sufficient natural gas in Sichuan province, (4) introducing some street sweeping and washing machines to sweep the road before the traffic volume peak period, (5) prohibiting vehicles that seriously fall short of the emission standard being driven into the city, (6) encouraging peasants not to burn the straw during

the harvest periods, (7) restricting fireworks displays in this city, (8) urging the industries and building companies to take some effective measures to prevent massive particles produced during the producing processes from dispersing into air.

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