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Original Research Paper

Spatiotemporal Variations of Ambient PM_{10} Concentrations in Nanchong, a Big City of Southwest China

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ABSTRACT

In order to further improve urban air quality, this study applied hourly PM_{10} mass concentrations in 5 monitoring stations during 2008-2012 to discuss spatiotemporal variations in Nanchong city, southwest China. The results showed that the annual mean PM_{10} concentrations during 5 years was 61.4μg/m^3, and the concentrations order of 5 stations was JC (65.4μg/m^3)>SW(64.6μg/m^3)>JL(60.9μg/m^3)>LY(60.4μg/m^3)>GP(55.9μg/m^3). The monthly mean concentrations in winter and spring were higher than in fall and summer. There was no obvious ñweekend effectòin Nanchong and it was illustrated that the contributions to PM_{10} of vehicle exhaust could be smaller. The hourly concentrations were 54.8~68.1μg/m^3 from 0:00 to 23:00 and the maximum appeared at 12:00 and 21:00 for each station. In addition, the influencing factors for PM_{10} were straw burning, fireworks and dust storms. The causes of these PM_{10} variations need to be studied deeply.

INTRODUCTION

With the rapid urbanization and industrialization, the urban air quality has worsen in many cities and it has been widely concerned. PM_{10} (inhalable particulate matter with aerodynamic diameter less than or equal to 10μm) is one of main air pollutants. It is a complex mixture of small and large particles which usually come from smoke and dust of industrial processes, incineration of refuse, heat and power generation, road traffic, construction, agriculture, as well as gas flaring and other natural sources. However, it has adverse impacts on visibility and climate change (Efe & Efe 2008, Jacob & Winner 2009, Sharia et al. 2014). Therefore, the concentrations of PM_{10} have been studied extensively in many western countries and Asian countries (Lee et al. 2011, Li et al. 2012, Pires & Martins 2012, Vicente et al. 2012).

In recent days, the air quality indexes were more than 200 in Nanchong, southwest China, which is located in Chengdu-Chongqing Economic Zone (CCEZ). The values on February 23, 2014 was 247 which means serious pollution (Wan et al. 2011). Thus, it is of great significance to study the spatiotemporal variations of ambient PM_{10} concentrations in Nanchong just like a large city in domestic. In order to further improve urban air quality and adapt to sustainable development in Nanchong, this paper will use hourly PM_{10} mass concentration data to analyse the temporal and spatial distribution of PM_{10}. The results can better reflect the changing trend of air pollution and provide useful help for air pollution prevention.

MATERIALS AND METHODS

Study area: Nanchong is located in northeast of Sichuan province and north of CCEZ, at 30°35'-31°51'N, 105°27'-106°58'E. It falls within the subtropical humid monsoon climate. The annual average temperature is about 17°C and the annual average precipitation is about 1100mm. There are four distinctive seasons and the prevailing wind directions are northwest wind in Nanchong. The city covers an area of 101km^2 with a population of 1.06 million in 2013.

Data and methods: The hourly PM10 mass concentration data were taken from Nanchong Environmental Monitoring Center, and those were collected at six monitoring stations (XS as background not calculated) (Fig. 1) by Online Air Quality Monitoring System from January 2008 to December 2012. The QA/QC procedures were carried out and maintained throughout the years, including regular instrument calibration with Standard Reference Materials (SRM). The capture rate of PM10 was 96.3%. The daily average concentrations were divided by 24 to get hourly average, and the monthly and yearly average can be calculated by the same way. The measurement technique of PM10 is β-Ray attenuation analyzer (Thermos Anderson FH 62 C14 Series), and the detection limit is 1μg/m^3. According to National Ambient Air Quality Standard (GB3095-2012),

Fig. 1: Locations of PM_{10} monitoring stations in Nanchong.

the level limits for evaluating air quality were 70µg/m^3 (annual average) and 150µg/m^3 (daily average).

RESULTS AND DISCUSSION

Annual variations of PM_{10}: The annual mean PM_{10} concentration during 5 years was 61.4µg/m^3, and it decreased from 62.8µg/m^3 in 2008 to 59.5µg/m^3 in 2012 (Fig. 2). The PM_{10} concentrations in Beijing (122µg/m^3), Shanghai (88µg/m^3), Guangzhou (72µg/m^3) and Chengdu (115µg/m^3) were higher than Nanchong. The concentrations in Ireland (40µg/m^3), Tokyo (24µg/m^3) and Europe (24µg/m^3) were less than Nanchong (Li et al. 2013, Li & Zhou & Liu 2014). In addition, the concentrations order of 5 stations was JC (65.4 µg/m^3)>SW (64.6µg/m^3)>JL (60.9µg/m^3)> LY(60.4µg/m^3) > GP(55.9µg/m^3) below the second-level. According to the characteristics of spatial variations, the annual mean concentrations at JC in 2011 (74.8µg/m^3), 2012 (86.9µg/m^3) and LY in 2008 (76.7µg/m^3), 2009 (73.7µg/m^3) exceeded the second-level. It might be due to refinery waste gas emissions and construction activities. But the concentrations were lower than the second-level at SW, GP and JL and the concentrations at LY presented a downward tendency from 2008 to 2012, which were related to government efforts of strengthening management and monitoring vehicle exhausts, changing energy structure and pursuing cleaning production process.

Monthly variations of PM_{10}: There were obvious fluctuations for monthly mean mass concentrations at each station from 2008 to 2012 in Fig. 3. The maximum concentrations appeared in winter (78.6µg/m^3 in December and 76.2µg/m^3 in January) exceeded the annual mean second-level limit. Oppositely, the minimums lower than 60µg/m^3 were in summer and autumn. At SW station located beside Beihu road and Lianchi road, the concentrations in January (81.7µg/m^3) and February (81.1µg/m^3) were higher than others. The maximum in April (57.9µg/m^3) and May (59.0µg/m^3) appeared at LY. And at JC, the concentrations in November (76.9µg/m^3) and December (84.5µg/m^3) exceeded the standard limit of 70µg/m^3. The concentrations at JC, LY and SW were higher than GP and JL. Due to the high temperature, the strong solar radiation and air convection in summer, PM_{10} spreads easily. And the high rainfalls make the PM_{10} concentrations lower in summer and autumn. In addition, the adverse weather conditions in winter such as high relative humidity and temperature inversion lead PM_{10} not to migrate promptly. Because of desiccation, sand and dust in spring, the concentrations of PM_{10} were also high.

Daily variations of PM_{10}: Taking November 2008 as an example to discuss daily variation of PM_{10} due to it being the highest levels in the 5-year study period, the monthly mean concentration was 91.8µg/m^3 greater than the annual mean second-level. Due to human activities in the urban areas, there should be differences between weekdays and weekends, which is named as "weekend effect". The industrial production and the cars have discharged more PM_{10} on weekdays, therefore, the concentrations remained at a high level from Monday to Friday (Tang et al. 2008). It can be seen

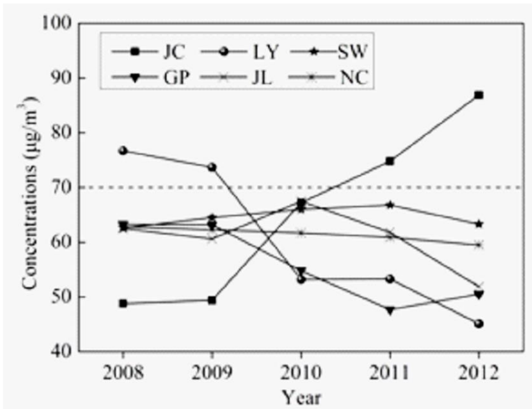

Fig. 2: Annual mean concentrations of $PM_{10.}$

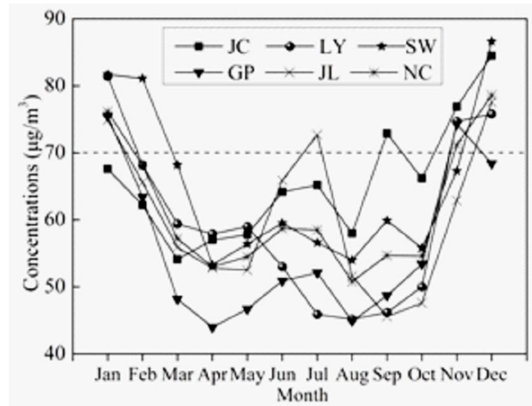

Fig. 3: Monthly mean concentrations of $PM_{10.}$

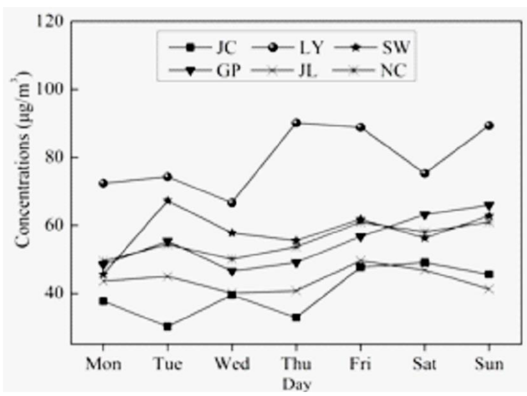

Fig. 4: Daily mean concentrations of $PM_{10.}$

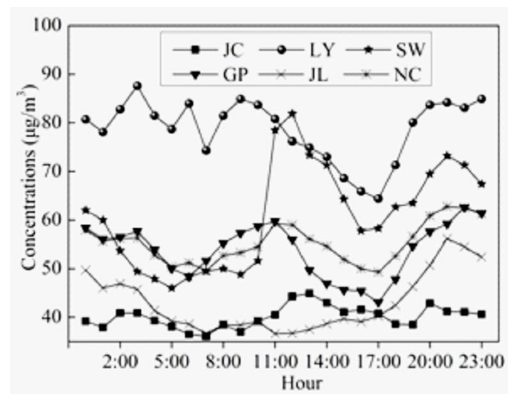

Fig. 5: Hourly mean concentrations of $PM_{10.}$

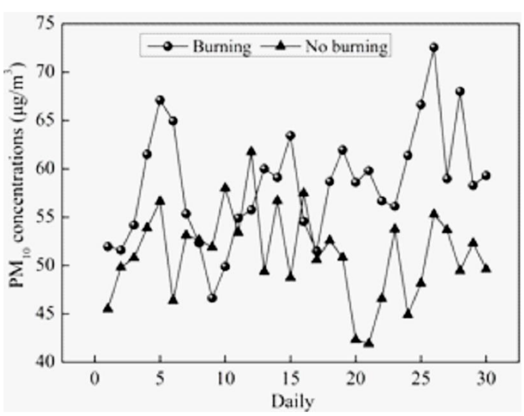

Fig. 6: PM_{10} concentrations during biomass burning activity and no biomass burning activity in Nanchong.

clearly in Fig. 4, that the concentrations have no significant difference between them. It showed that the contributions of human activities and vehicle exhaust to PM_{10} values were smaller. In addition, the maximum appeared at LY (66.7~90.2μg/m^3) followed by SW (45.6~67.3μg/m^3) that were less than the daily mean second-level limit (150μg/m^3). The result could be caused by industrial waste gas pollution migrating to SW.

Hourly variations of PM_{10}: The concentration variations of PM_{10} at each station in November 2008 are shown in Fig. 5. The urban mean PM_{10} concentrations were lower than the daily mean second-level limit (150μg/m^3); that values were 54.8~68.1μg/m^3 from 0:00 to 23:00. The concentrations at LY (64.6~87.6μg/m^3) and SW (46.0~81.9μg/m^3) were apparently higher than JC (36.1~44.9μg/m^3), GP (43.1~62.6μg/m^3) and JL (36.6~56.2μg/m^3). In Fig. 5, there were the same changing trends for each station, two peaks (07:00~12:00 and 17:00~21:00) and slack periods (23:00~07:00 and 13:00~16:00). It is the peak of people activities, transportation and industrial production during 07:00 and 12:00, and they discharge plenty of PM_{10} into the atmosphere. Because the temperature is lower and airflow is stabilized in the morning, the PM_{10} concentrations were higher. Later in the evening, the airflow motion decreases and the contaminant

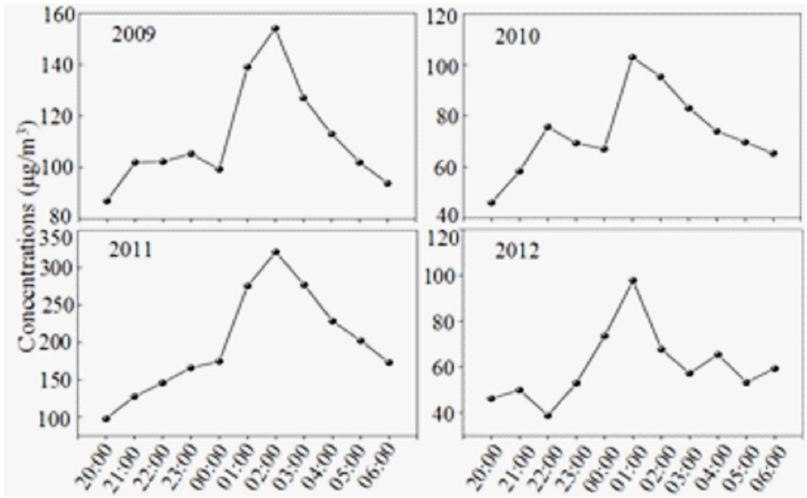

Fig. 7: Hourly PM_{10} concentrations in Nanchong during New Year's Eve from 2009 to 2012.

transport spreads slowly, so PM_{10} enlarge. On the other hand, in the afternoon, the temperature is high and the relative humidity is low. It is conducive to the spread of PM_{10}. During 23:00~07:00, the ability of air for self-purification is strong and the PM_{10} sources are decreasing in the period, so the concentrations were lower. The factors affecting the PM_{10} concentrations were human activities, transportation and industrial production and meteorological conditions.

Influencing factors: Agriculture crop residue burning is an important source of atmospheric pollution (Badarinath & Kharol & Sharia 2009, Ryu et al. 2007), especially, the burning activities happened during summer harvest time (Li et al. 2010). The area of growing in Nanchong is 200,000 hectares, the crop straws were mostly burned in the open field during summer harvest time. The generated air pollutants spread into the urban air. Fig. 6 shows the variations of the PM_{10} concentrations in June (burning activities) and August (no burning activities). The highest concentration in June was 72.6 μg/m³, and the days of exceeded the daily mean first-level air quality limit (50 μg/m³) accounted for 93.3%. However, the highest concentration in August was 61.8 μg/m³, and the days of exceeding the first-level air quality limit accounted for 60.0%. Therefore, the PM_{10} concentrations affected by burning activities (in June) were higher during the five years.

Fireworks are the most unusual sources of pollution in atmosphere. These pollution episodes are responsible for high concentrations of particles (especially metals and organic compounds) and gases (Barman et al. 2008, Chatterer et al. 2013, Wang et al. 2007, Vecchi et al. 2008). Fireworks displays are another major local air pollution source in Nanchong. This is especially true during the Spring Festival holiday when it is tradition for people to set off fireworks. The Spring Festival's Eve was celebrated on January 25-26 in 2009, February 13-14 in 2010, February 2-3 in 2011 and January 22-23 in 2012.

Records showed that the PM_{10} concentrations increased instantaneously from 23:00 to 02:00 (Fig. 7). The PM_{10} concentrations at 01:00-03:00 on February 3, 2011(276.0~321.3 μg/m³), were extremely higher than the daily mean third-level (250 μg/m³) and concentrations at 00:00-23:00 (166.0~174.8 μg/m³) and 04:00-06:00 (173.3~228.8 μg/m³) exceed the second-level limit. The results showed that fireworks were one of the most important air pollution sources in Nanchong.

Dust storm is also one of the severely disastrous weather that may have a long-term, harmful effect and may destroy

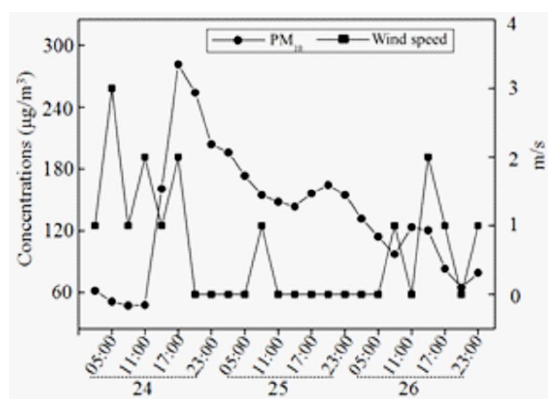

Fig. 8: Hourly PM_{10} concentrations and wind speed of April 24, 25 and 26 in 2009.

the atmospheric and ecological environment in the arid and semiarid regions (Han & Cui & Tao 2012). Research has shown that dust storms can even travel across the Pacific Ocean and reach the western coast of North America (Wang et al. 2003). The dust storms comes from the Gobi Desert that lies within Mongolia and northern China and the Taklimakan Desert in western China (Sun & Zhang & Liu 2001). In the past years, Beijing and Chengdu were affected by dust storms (Tao et al. 2013, Zhang et al. 2009). Although Nanchong is far away from north China, its air quality can still be influenced by dust storms under certain conditions. Taking April 25, 2009 as an example, when a dust storm occurred in Gansu, Ningxia and Inner Mongolia on April 22-25, 2009 (Wang & Hu & Jin 2013). The dust storm from the northwest made the PM_{10} concentrations come out 281.4 $\mu g.m^{-3}$ at 20:00 on April 24, 2009 exceeded the daily mean third-level, then the PM_{10} concentration gradually decreases until April 26. This was a typical high concentrations process caused by remote source during the daytime. Fig. 8 illustrated the sharp increase of PM_{10} appeared and stayed for several hours with high wind speed on the specific day.

CONCLUSION

In this paper, we reported spatio-temporal variations of ambient PM_{10} concentrations and evaluated the air quality in Nanchong from 2008 to 2012. The annual mean PM_{10} concentration was 61.4$\mu g/m^3$ which was less than 70$\mu g/m^3$. The order of values was JC(65.4$\mu g/m^3$) > SW(64.6$\mu g/m^3$) > JL (60.9$\mu g/m^3$) > LY(60.4$\mu g/m^3$) > GP(55.9$\mu g/m^3$). While, the monthly mean mass concentrations in spring and winter were higher than summer and fall. The maximum values appeared in December and January. There were no significant differences between weekdays and weekends. It was illustrated that there was no "weekend effect" and the contributions to PM_{10} values of human activities and vehicle exhaust were smaller. The hourly PM_{10} concentrations were 54.8~68.1 $\mu g/m^3$ and there were two peaks (07:00~12:00 and 17:00~21:00) and slack periods (23:00~07:00 and 13:00~16:00). The precise causes of these variations need to be studied deeply. In addition, the influencing factors for PM_{10} were straw burning, fireworks and dust storms.

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