Chapter 2
Characteristics of Major Air Pollutants in China

Lihong Ren, Wen Yang, and Zhipeng Bai

Abstract Following the rapid development of China's economy, air pollution has become more and more serious. Air pollution in China presents complex pollution characterized by high $PM_{2.5}$ and O_3 concentration. This study presents an overview of the status of air quality and emission in China and discusses the temporal and spatial distribution of major pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_X, and O_3). The results show that the reduced emissions have improved the air quality in China. However, the Chinese National Ambient Air Quality Standard (CNAAQS) for PM_{10} and $PM_{2.5}$ still be exceeded in many cities of China in 2015. A total of 77.5% (for $PM_{2.5}$) and 65.4% (for PM_{10}) of the monitoring cities were found to be exceeded CNAAQS. The average annual O_3 concentration was increasing during 2013–2015, and 16% of the total cities in 2015 did not meet the CNAAQS, indicating that O_3 pollution should be paid more attention. For NO_2 and SO_2, the exceedances of CNAAQS are rare. $PM_{2.5}$, PM_{10}, and SO_2 concentrations are higher in northern than in southern regions. High NO_2 occurred in Beijing-Tianjin-Hebei and Yangtze River delta region. Secondary particles formation and motor vehicle exhaust were the main sources of $PM_{2.5}$ in megacities. Dust was the main source for PM_{10}. The formation of O_3 is VOC-limited in urban areas of China and NO_X-limited in nonurban areas.

Keywords Air pollutants • Pollution characteristics • Emission status • China

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2.1 Introduction

In recent years, China's economy has developed rapidly, the process of urbanization and industrialization has been speeded up, and energy consumption has increased. The statistics shows that China's gross domestic product (GDP) annual growth rate was 6.9–9.5% during 2011–2015 [17]. According to China Vehicle Environmental Management Annual Report, the vehicle population in 2015 was 279 million [13–15]. Since the late 1970s, the total energy consumption has greatly increased from 571 million tonnes of coal equivalence (Mtce) in 1978 to 4300 Mtce in 2015 [18]. Coal is the major fraction of energy consumption, accounting for 70% of China's energy consumption. Coal burning is the major source of ambient sulfur dioxide (SO_2), nitrogen oxides (NO_X), and soot.

With the development of economy, regional complex air pollution (characterized as a complex status of ozone (O_3) and fine particle ($PM_{2.5}$)) is one of the major environmental problems. Since 2013, heavy pollution events occurred frequently in China with 75% of cities and eight million people suffering from haze pollution, which constrains sustainable development of society and economy and threatens human health [8]. Air quality in China ranked the second to last in 180 countries, only better than Bangladesh [6].

Air pollutants can cause a variety of health problems. Exposure to high concentration of particulate matters can increase mortality or morbidity; excessive O_3 can cause breathing problems, trigger asthma, reduce lung function, and cause lung diseases; long-term and peak exposures to high NO_X can increase symptoms of bronchitis in asthmatic children; and SO_2 can affect the respiratory system and the functions of the lungs and causes irritation of the eyes [27]. The 1948 Donora smog caused by SO_2 and its oxides killed 20 people and sickened 5911 people [4]. The 1952 Los Angeles photochemical smog episode killed 400 people and a great many of people with red eyes, swollen throat, inflammation, and other respiratory diseases [23]. Therefore, it is both important and valuable to study the atmospheric pollution status and the variation characteristics of air pollution and its influential factors.

In this study, based on the data of air pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_X, and O_3) obtained from the national air pollution monitoring network in China, we will present an overview and analysis of air quality in China, analyze emission and pollution characteristics of major atmospheric pollutants, and then discuss temporal and spatial distributions of these pollutants. The study results will provide basic information for studying the health effects of air pollutants.

2.2 Chinese National Ambient Air Quality Standard

The Chinese National Ambient Air Quality Standard was issued firstly in 1982, when concentration limits for total suspended particulates (TSP), SO_2, NO_2, lead, and BaP were set. This standard was both strengthened and expanded in 1996. In

Table 2.1 Chinese National Ambient Air Quality Standard (GB 3095-2012) vs. WHO AQG

Pollutants	Averaging time	Chinese AQC(μg/m^3)		
		Grade I	Grade II	WHO AQG (μg/m^3)
$PM_{2.5}$	Annual	15	35	10
	24-h	35	75	25
PM_{10}	Annual	40	70	20
	24-h	50	150	50
SO_2	Annual	20	60	–
	24-h	50	150	20
	1-h	150	500	200
NO_2	Annual	40	40	40
	24-h	80	80	–
	1-h	200	200	200
O_3	Maximum daily 8-h	100	160	100
	1-h	160	200	
CO	24-h	4000	4000	
	1-h	10,000	10,000	

2000, the standard was updated with less stringent limits for certain pollutants. In February 2012, China released a new ambient air quality standard, GB 3095-2012, which set limits for the first time on $PM_{2.5}$ and Maxium daily 8-h ozone (Table 2.1). Meanwhile, the standard threshold of PM_{10} and oxynitride has also been tightened up.

Current air quality standards include two grades of limit values. Grade I standards apply to special regions such as national parks. Grade II standards apply to all other areas, including urban and industrial areas.

The 24-h and annual $PM_{2.5}$ limit values are set at 75 μg/m^3 and 35 μg/m^3 (Table 2.1). WHO AQG is stricter than the Chinese National Ambient Air Quality Standard. The recommended WHO AQG short-term (24-h) and long-term (annual average) values were 25 μg/m^3 and 10 μg/m^3 for $PM_{2.5}$. The United States published the National Ambient Air Quality Standard for $PM_{2.5}$ in 1997 (24-h average, 65μg/m^3; annual average, 15 μg/m^3), but the Ministry of Environmental Protection of the People's Republic of China did not published the National Ambient Air Quality Standard for $PM_{2.5}$ until 2012.

The 24-h and annual PM_{10} limit values are set at 150 μg/m^3 and 70 μg/m^3. WHO AQG for PM_{10} is lower than the Chinese National Ambient Air Quality Standard (Table 2.1). The recommended WHO AQG short-term (24-h) and long-term (annual average) values were 50 μg/m^3 and 20 μg/m^3 for PM_{10}.

The Chinese National Ambient Air Quality Standard (GB 3095-2012) set by the Ministry of Environmental Protection of the People's Republic of China (MEP) for SO_2, as well as WHO guideline, is shown in Table 2.1. The limit value for the annual and 24-h mean SO_2 concentration are set at 60 μg/m^3 and 150 μg/m^3. Unlike the usual 24-h and annual mean levels, WHO recommends that SO_2 follows a more stringent 10-min and 24-h intervals based on recommendations resulting from epidemiological studies. The yearly guideline is not needed since the 24-h guideline would be sufficient in assuring low annual average level.

The limit value for the annual, 24-h, and 1-h mean NO_2 concentrations is set at 40 μg/m³, 80 μg/m³, and 200 μg/m³, respectively, which was identical to WHO AGQ. A maximum daily 8-h O_3 mean concentration was set at 160 μg/m³ and 1-h mean was 200 μg/m³ in China. The WHO AQG for O_3 is a daily maximum 8-h mean concentration of 100 μg/m³, as shown in Table 2.1. This recommended limit was reduced from the previous level of 120 μg/m³, based on recent conclusive associations between daily mortality and lower O_3 concentrations [27].

2.3 Characteristics of Major Air Pollutants

2.3.1 Fine Particle ($PM_{2.5}$)

2.3.1.1 Characteristics of $PM_{2.5}$ Pollution

China is one of the countries worst hit by $PM_{2.5}$ pollution. According to the global map of $PM_{2.5}$ published by NASA [16], the $PM_{2.5}$ pollution in north and east of China is the most serious, which was higher than that in India (Fig. 2.1). Recently, following the change of energy consumption structure, the pollution characteristics of particulate matters in China has changed from "coal smoke pollution" to "complex pollution," which is characterized by high $PM_{2.5}$ and O_3 concentration.

According to the report of the China air quality database, the CNAAQS limit value for $PM_{2.5}$ was exceeded in many cities of China in 2015. $PM_{2.5}$ has the highest percentage of exceedance among monitored pollutants. In 2015, the annual $PM_{2.5}$ concentrations in 338 cities were 11–125 μg/m³ with an average of 50 μg/m³, which was 0.43 times higher than the Chinese National Ambient Air Quality Standard (35 μg/m³). The exceedances occurred in 77.5% of the case in all the monitoring

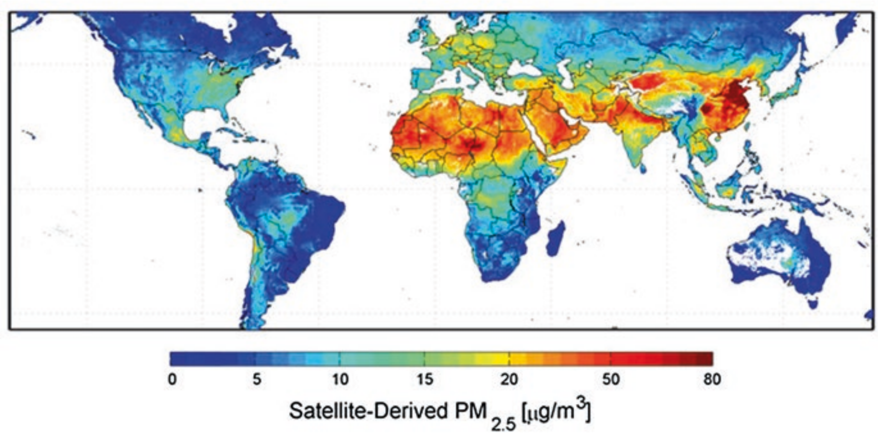


Fig. 2.1 Global satellite-derived map of $PM_{2.5}$ averaged over 2001–2006 [16]

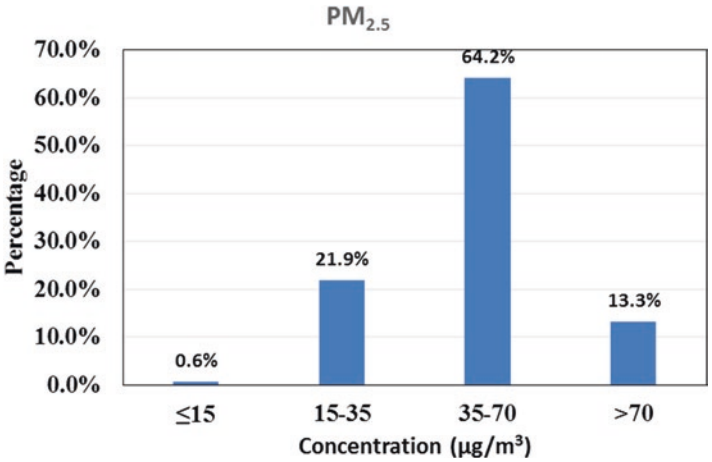


Fig. 2.2 Percentage of cities at different $PM_{2.5}$ concentration levels in 338 cities, 2015 (Data sources: MEP [13])

cities (Fig. 2.2). None of the cities were compliant with annual $PM_{2.5}$ World Health Organization (WHO) air quality guideline (10 μg/m^3). The proportion of the number of days exceeded the Chinese National Ambient Air Quality Standard was about 17.5% [13].

$PM_{2.5}$ has obvious spatial and temporal distributions related to the patterns of source emissions, chemical reaction mechanism, regional transport, and other meteorological conditions (such as dry and wet deposition). Figure 2.3 shows the spatial distribution of $PM_{2.5}$ in 2015 in China. As shown in Fig. 2.3, higher $PM_{2.5}$ concentration is mainly concentrated in Beijing-Tianjin-Hebei region, the north and middle part of Shandong province, the south and middle part of Henan province, and most of Hubei province. Generally, $PM_{2.5}$ annual concentration in the northern region was much higher than in the southern region. A number of studies have revealed that the higher concentrations in the northern region were related to the emissions from fossil fuel combustion and biomass burning. The colder north burns much more coal for winter heating and has more heavy industry, which emits a large amount of particulate matter [5].

With respect to seasonal variation, $PM_{2.5}$ has higher concentration in winter than that in other seasons and the lowest appeared in the summer (Fig. 2.4). The highest seasonal average concentrations were less than twice the lowest average values. Although the low temperature in the winter limited the secondary formation of particles, more frequent occurrences of the stagnant weather conditions caused the accumulation of atmospheric particles and high concentration episodes. Lower concentrations were observed in summer as particulate matters are washed out due to wet deposition.

Because many effective measures have been carried out to improve the air quality, $PM_{2.5}$ annual concentration in China has decreasing trend according to observation data in the recent 3 years (see Fig. 2.5). The annual average of $PM_{2.5}$ in 74 key

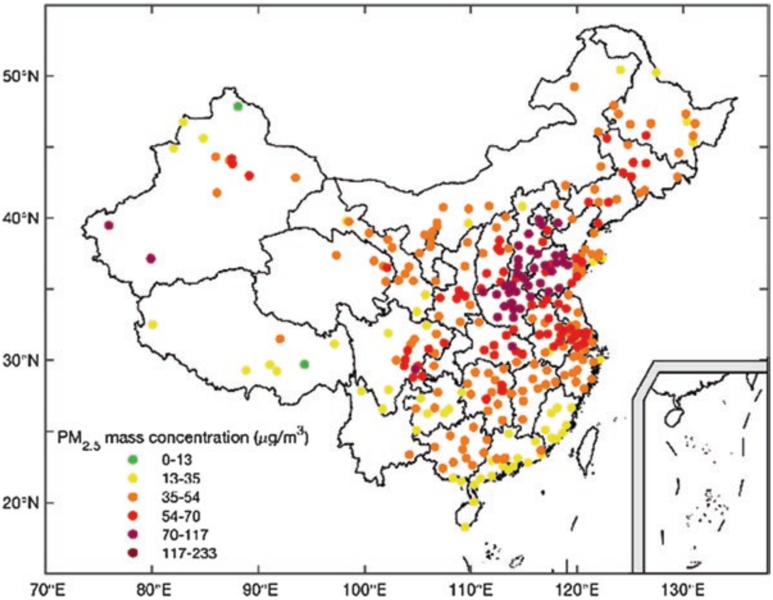


Fig. 2.3 Spatial distribution of $PM_{2.5}$ annual average concentrations in 2015 (Data sources: National air pollution monitoring network in China)

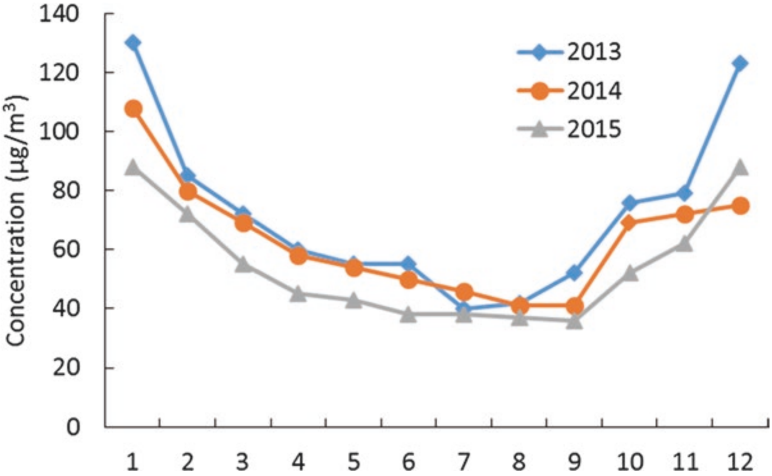


Fig. 2.4 Monthly variations of $PM_{2.5}$ in 2013, 2014, and 2015 (Data sources: National air pollution monitoring network in china)

cities was 72 μg/m^3 in 2013, and it decreased to 55 μg/m^3 in 2015. The government has taken measures and $PM_{2.5}$ has decreased over the recent years; however, $PM_{2.5}$ in most Chinese cities is still far above the Chinese National Ambient Air Quality Standard (GB 3095-2012). In China, the $PM_{2.5}$ has large portion of PM_{10} with 50–85%.

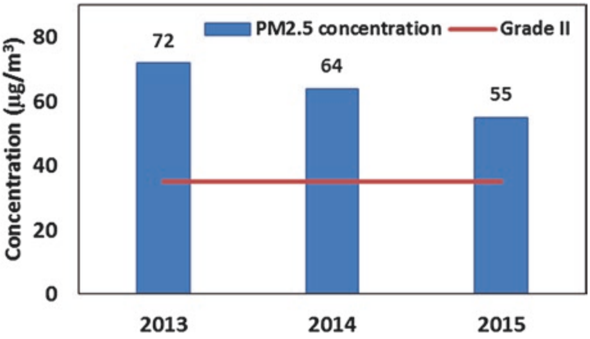


Fig. 2.5 Annual variation trends of $PM_{2.5}$ in 74 key cities in the recent 3 years (Data sources: MEP [11–13])

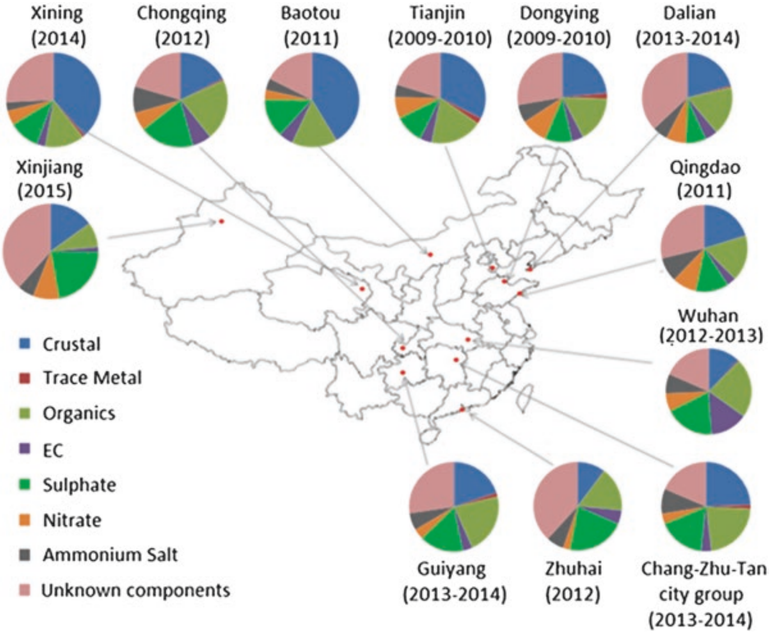


Fig. 2.6 $PM_{2.5}$ speciation in China [1]

2.3.1.2 Chemical Composition and Source Apportionment of $PM_{2.5}$

Particulate matter originated from both primary emission sources and reaction of precursor gases, such as sulfur dioxide (SO_2), nitrogen oxides (NO_X), ammonia (NH_3), and volatile organic compounds (VOCs). The main precursor gases NH_3, SO_2, and NOx react in the atmosphere to form ammonium, sulfate, and nitrate compounds. These compounds form new particles in the air or condense onto preexisting ones and form so-called secondary inorganic aerosols. Figure 2.6 shows the chemical composition of $PM_{2.5}$ in most cities of China. The chemical composition of $PM_{2.5}$ is varied at different cities, which is related with pollution sources and

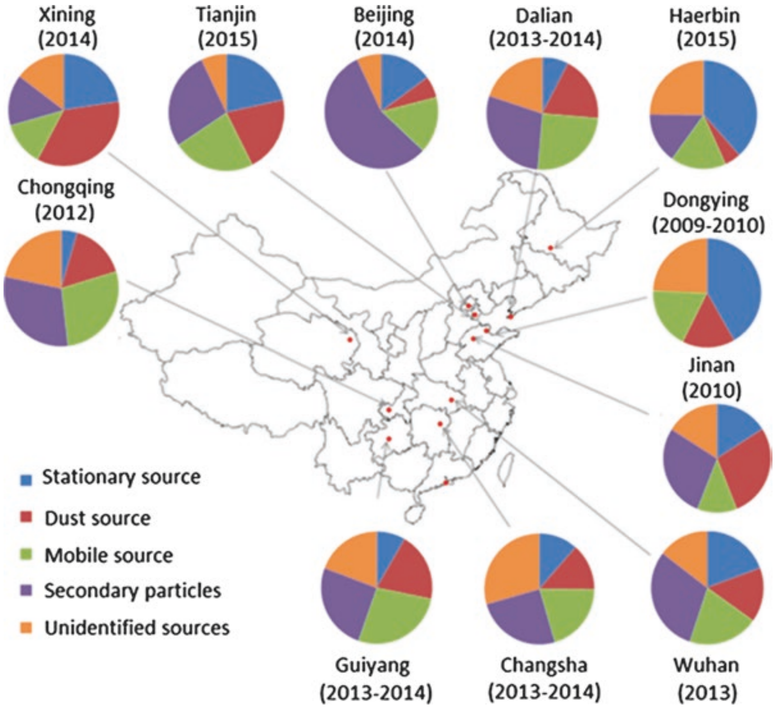


Fig. 2.7 The major sources of $PM_{2.5}$ in many Chinese cities [1]

meteorological conditions. In general, the crustal elements and organic matter are major species of $PM_{2.5}$. Secondary particles, such as sulfate, nitrate, and ammonium salt, have higher fractions in the eastern cities. Yang et al. [30] and He et al. [5] also find secondary ions, organic carbons, and crustal material that are the main components in urban and rural sites of China. This result indicated that there are more local formation/production and regional transport of the secondary aerosols in the eastern region, thus more intensive characteristic of "complex atmospheric pollution" compared to the western region.

$PM_{2.5}$ can be emitted directly from selected sources (primary PM), such as combustion and industry, or generated by gas-to-particle conversion in the atmosphere (secondary PM). Figure 2.7 shows the major sources of $PM_{2.5}$ in many Chinese cities. From it we can see that source contribution rates are varied in different cities. In generally, secondary particles formation and motor vehicle exhaust were the main sources of $PM_{2.5}$ in megacities (such as Beijing, Wuhan, and Chongqing). $PM_{2.5}$ in western cities (such as Xining) was influenced mainly by dust. The contribution of stationary sources, including coal combustion and industrial emissions, shows a downward trend from north to south. During the haze pollution events, a large fraction of $PM_{2.5}$ was secondary species, that is, secondary organic aerosol (SOA) and secondary inorganic aerosol (SIA, sulfate, nitrate, and ammonium). The contribution of primary particulate to $PM_{2.5}$ was small [8].

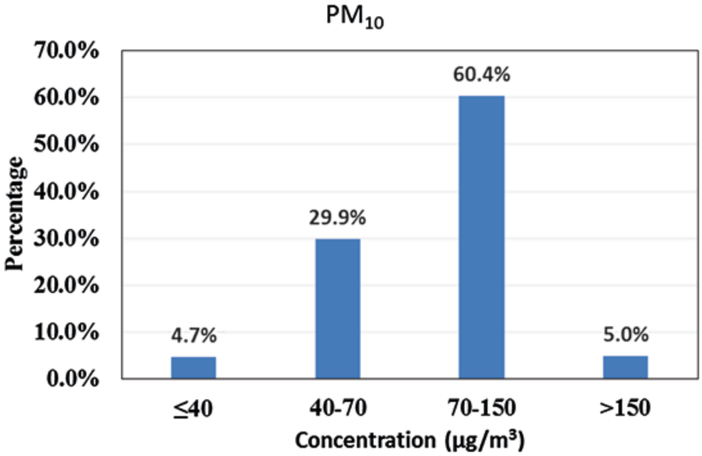


Fig. 2.8 Percentage of cities at different PM_{10} concentration levels in 338 cities, 2015 (Data sources: MEP [13])

2.3.2 *Inhalable Particulate Matter (PM_{10})*

2.3.2.1 Characteristics of PM_{10} Pollution

In China, PM_{10} remains an important pollutant. In 2015, PM_{10} concentrations at 65.4% of the monitoring cities were found to be exceeded than the CNAAQS (Fig. 2.8). The annual PM_{10} concentrations in 338 cities were 24–357 μg/m^3 with an average of 87 μg/m^3, which exceeded the Chinese National Ambient Air Quality Standard (70 μg/m^3). Days of daily concentrations exceeding the air standard was about 12.1% of all monitoring days.

Figure 2.9 shows the spatial distribution of PM_{10} in 2015. As shown in Fig. 2.9, PM_{10} annual concentration in the northern region was much higher than that in the southern region. The higher PM_{10} concentrations in the northern region were related to the influence of dust-sand.

The trends of PM_{10} in the recent 3 years in 74 key cities were calculated based on the officially reported data (Fig. 2.10). Although PM_{10} annual concentration also was decreasing trend, it was still far above the Chinese National Ambient Air Quality Standard (GB 3095-2012). The annual average of PM_{10} in 74 key cities was 118 μg/m^3 in 2013, and it decreased to 93 μg/m^3 in 2015 which was about 33% higher than the Chinese grade II standards.

PM_{10} has also obvious seasonal variation, showing the concentrations in winter were higher than that in other seasons (Fig. 2.11). The highest concentrations appeared in December and January. Lower concentrations were observed in July and August, which was related with the frequency of rain.

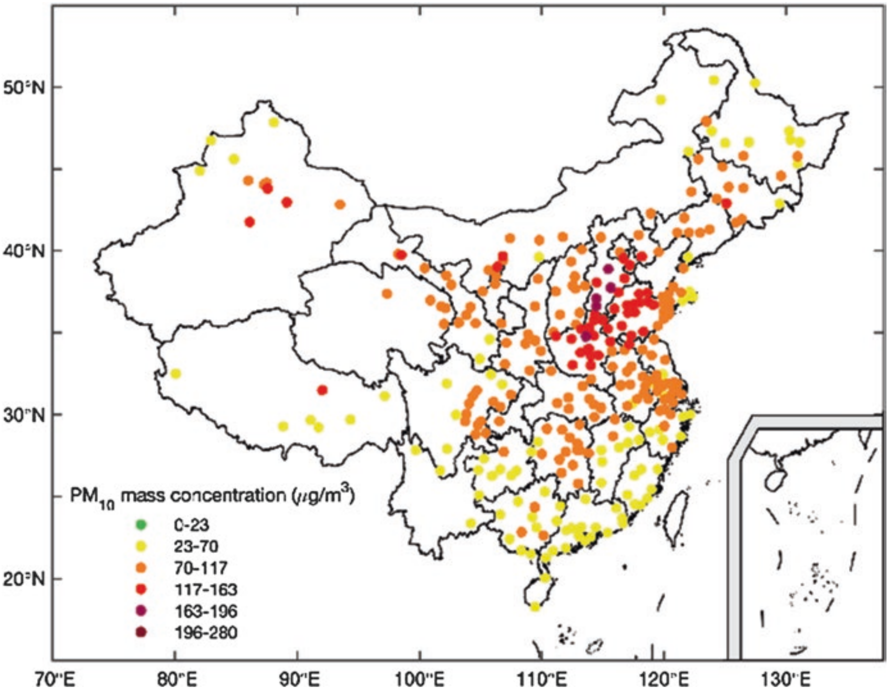
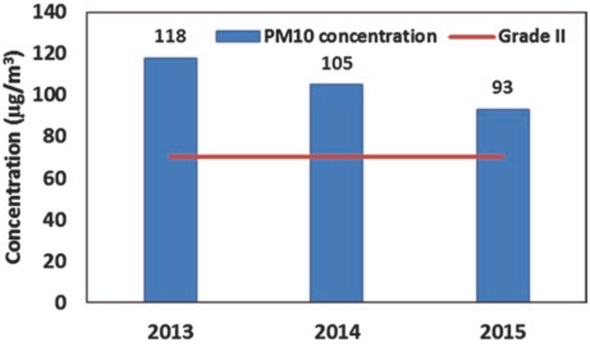


Fig. 2.9 Spatial distribution of PM_{10} annual average concentrations in 2015 (Data sources: National air pollution monitoring network in China)

Fig. 2.10 Annual variation tendency of PM_{10} in 74 key cities of China (Data sources: MEP [11–13])



2.3.2.2 Chemical Composition and Source Apportionment of PM_{10}

Soil dust was the first abundant component for PM_{10} in most cities of China. And the secondary aerosol was the second important component. Carbonaceous matter has also important contribution to PM_{10} mass concentration [2, 21].

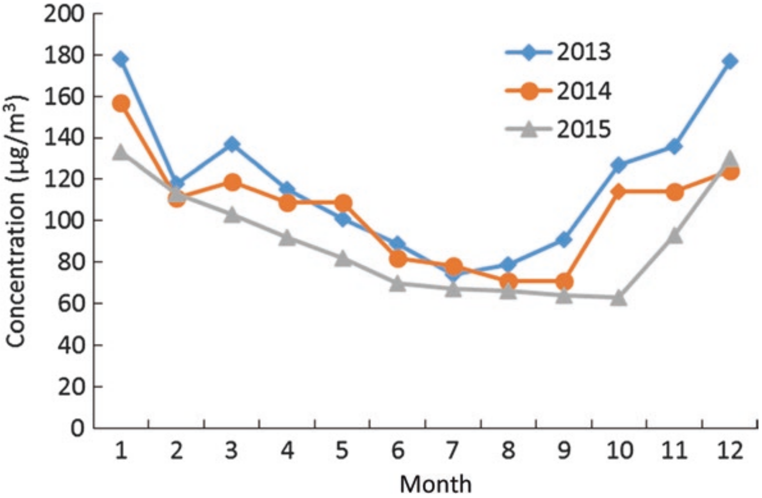


Fig. 2.11 Monthly variations of PM_{10} in 2013, 2014, and 2015 (Data sources: National air pollution monitoring network in china)

Figure 2.12 shows the major sources of PM_{10} in some Chinese cities. It can be found that dust was the main source for PM_{10}. Stationary source and mobile source also have important contribution to PM_{10} in the northern cities (such as Dalian, Shenyang, and Harbin).

2.3.3 Ozone (O_3)

2.3.3.1 Characteristics of O_3 Pollution

O_3 is a strong oxidant, formed from the reactions of precursors (VOCs, NO_X, and so on) and sunlight. The major health effect of O_3 is its effect on the respiratory systems. O_3 is the main component of photochemical smog. In 1974, the first photochemical smog events in China appeared in the Xigu Industrial District of Lanzhou City. Photochemical smog events have also appeared in some suburban regions. Photochemical smog, high O_3, and NO_X concentrations have gradually emerged into China’s three city clusters (Beijing-Tianjin-Hebei region, the Yangtze River Delta, and Pearl River Delta).

Although O_3 annual concentrations in the recent 3 years were lower than the CNAAQS, the average annual O_3 concentrations were increasing during 2013–2015 (as Fig. 2.13 shows), indicating that O_3 pollution should be paid more attention. Year-to-year differences in the O_3 levels are also induced by meteorological variations.

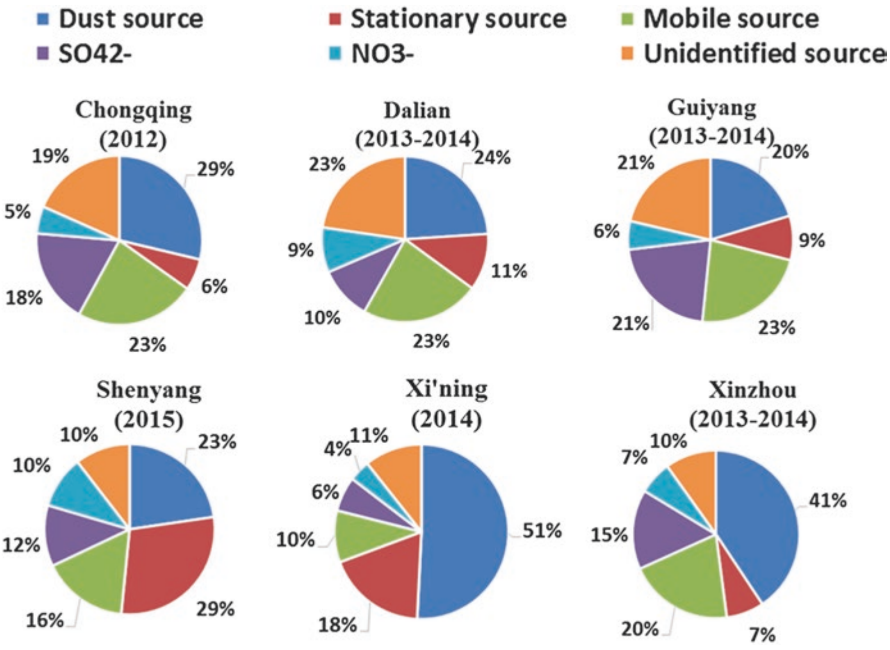


Fig. 2.12 The major sources of PM_{10} in many Chinese cities

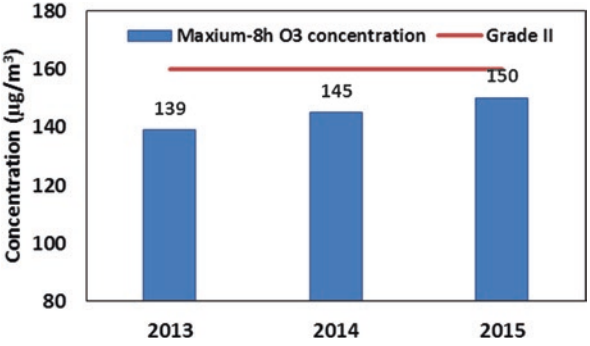


Fig. 2.13 Annual variation tendency of O_3 in 74 key cities of China (Data sources: MEP [11, 12, 13]

In 2015, the 90% of O_3 maximum daily 8-h mean concentrations in 338 cities were 62–203 μg/m^3 with an average of 134 μg/m^3. Sixteen percent of the total cities did not meet the CNAAQS (Fig. 2.14). Days of daily concentrations exceeding the air standard was about 4.6% of all monitoring days.

Differences in the distribution of O_3 precursor emission sources and climatic conditions in Europe result in considerable regional differences in O_3 concentrations. Higher ozone concentrations are observed, in general, in summer months as it is formed by photochemical reactions of NO_x and VOCs. Ozone concentrations tend to peak in early to midafternoon in areas where there is strong photochemical activity. The values indicate that ozone levels are within CNAAQS.

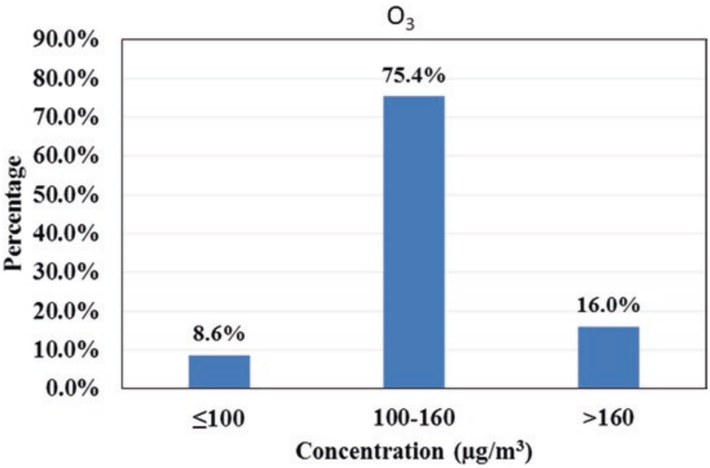


Fig. 2.14 Percentage of cities at different O_3 concentration levels in 338 cities, 2015 (Data source: MEP [13])

2.3.3.2 Sources and Formation of O_3

VOCs and NO_X emissions from motor vehicle were the major precursor gases of O_3 formation. Shao et al. [20] found that alkenes contribute a large fraction of VOC activity with 75%. The formation of O_3 is VOC-limited in urban areas of China and NO_X-limited in nonurban areas [7, 24, 31]. The influence of biogenic VOCs on O_3 formation was minor [19]. Heterogeneous NO_2 could increase the concentration. The influence of the reaction of NO_3 and N_2O_5 on O_3 was unimportant [29]. CH_4 and CO also play a role in O_3 formation in certain environments. Tie et al. [24] reported that oxidation of CO contributed to 54% of the total O_3 production in eastern region of China.

Both local formation and regional transport contributed to O_3 concentrations. Wang et al. [25] reported that the contribution from regional transport was about 17.8% of O_3 concentration in PRD. Tang [22] found that 40% of O_3 concentration in Beijing was from southern and southeastern regions.

Meteorological conditions have also a major influence on O_3 formation. High O_3 concentration was related to the occurrence of high-pressure synoptic systems [28].

2.3.4 Sulfur Dioxide (SO_2)

SO_2 has greatly contributed to acid rain and has adverse effects on ecosystems and the respiratory system [26]. It is also the main precursor to formation of particulate matter.

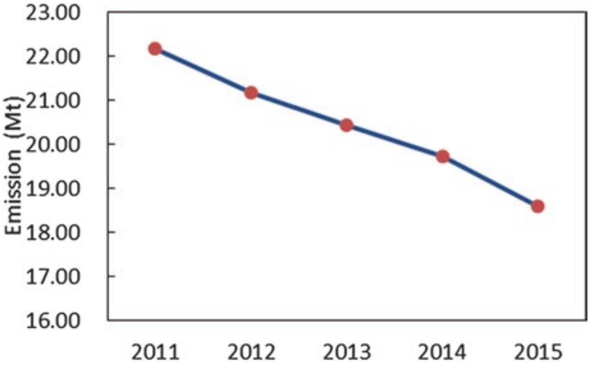


Fig. 2.15 Emission of SO_2 in China from 2011 to 2015 (Data sources: MEP [9–13])

Global SO_2 emissions have been dramatically reduced from 121 Tg to 103 Tg during the period of 1990–2010. Figure 2.11 gives the emission trend of SO_2 from 2011 to 2015 in China. Following the emission control legislations, SO_2 emissions have been decreasing dramatically. National emission of SO_2 in 2011 was about 22.17 Mt/year and it decreased to 18.59 Mt/year in 2015. In the period 2011–2015, SO_2 emission decreased by 16% (Fig. 2.15).

SO_2 is emitted primarily from fuels containing sulfur burning. The main anthropogenic emissions of SO_2 in China are derived from industrial sources (including power plant, domestic heating, and industrial production processes), and contribution from urban life source was little. As reported in "Annual Report of Environmental Statistics" [11], SO_2 emission in 2014 was about 19.7 Mt, and the contribution of industrial source and urban life source was about 88% and 12%, respectively.

With respect to the spatial distribution of SO_2 emission, Cao et al. (2010) found that the SO_2 emission in Shandong province, Hebei province, and Shanxi province was the highest, which was related to large consumption of coal in these regions [3]. The SO_2 emission in the western region (Qinghai, Xizang, and Gansu provinces) was relatively little.

In 2015, the annual SO_2 concentrations in 338 cities were 3–87 $\mu g/m^3$ with an average of 25 $\mu g/m^3$. The average concentration was lower than the Chinese National Ambient Air Quality grade II standard (60 $\mu g/m^3$). SO_2 concentrations at 3.3% of the monitoring cities were found to exceed the CNAAQS (Fig. 2.16). Days of daily concentrations exceeding the air quality standard was about 0.7% of all monitoring days.

Figure 2.17 shows the spatial distribution of SO_2 annual concentration in 2015. Maximum SO_2 annual concentrations were found in northern regions, especially in North China and Inner Mongolia region. It may be related to coal heating in China. The SO_2 concentration in southern regions was relatively lower.

Figure 2.18 shows the annual variation of SO_2 concentrations in 74 key cities of China. It is clear that the average annual values for 74 key cities show a decline trend in the recent 3 years, and all annual SO_2 concentrations stayed below the grade II standard value, indicating that the measures taken to control SO_2 pollution were effective.

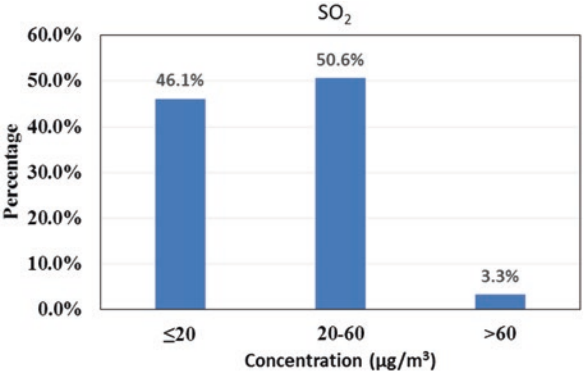


Fig. 2.16 Percentage of cities at different SO_2 concentration levels in 338 cities, 2015 (Data sources source: MEP 11)

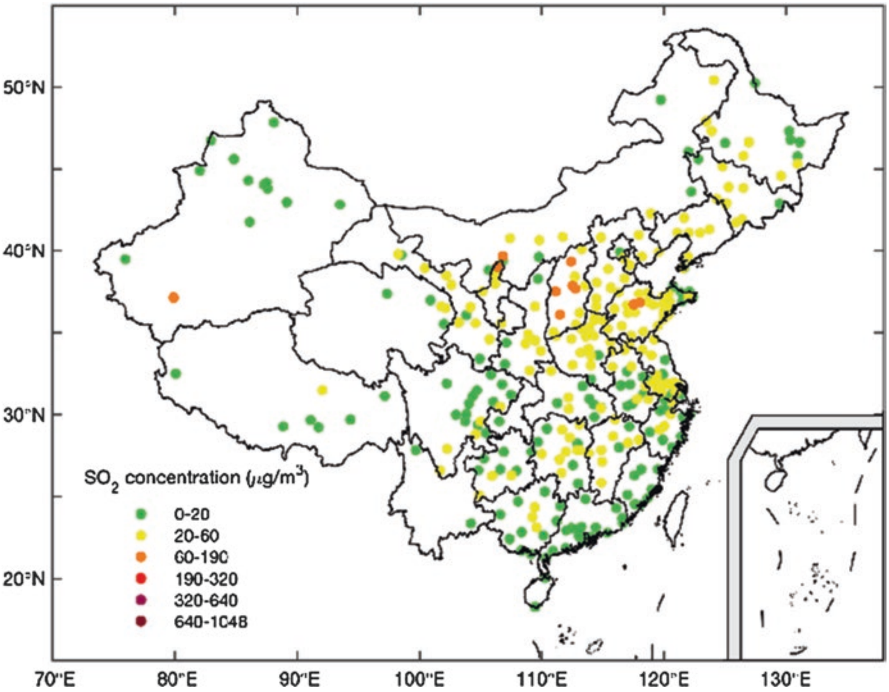
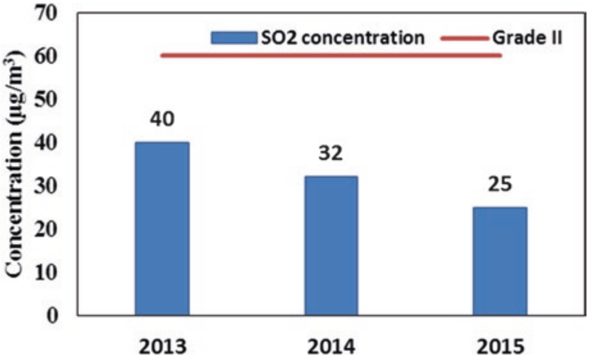


Fig. 2.17 Spatial distribution of SO_2 annual average concentrations in 2015 (Data sources: National air pollution monitoring network in China)

SO_2 shows the highest concentration in the winter and the lowest in the summer, which is due to the effects of emission sources and meteorological conditions. The energy structure was based on coal in China. Energy for heating is mainly coal in winter and these coals contain high-sulfur fraction over 0.5%, which cause the higher emission in winter. In addition, slow winds and shallow mixing layers occur more frequently in winter, trapping the pollutants near the surface and leading to high concentrations.

Fig. 2.18 Annual variation tendency of SO_2 in 74 key cities of China (Data sources: MEP [11–13])



2.3.5 Nitrogen Oxides (NO_X)

Vehicle is the main contributor of NO_X. Although the vehicle population increased by about 14.9% per year during 2007–2015 in China, the NO_X emissions have decreased obviously by about 23% during 2011–2015. This indicated that the control measure for NO_X was effective (Fig. 2.19).

In many developed counties, the main emission sources of NO_X are mobile vehicles. In the United States, 57.5% of NO_X emission was from mobile sources, with fuel combustion and industrial processes only account for 24.2% and 8.4%, respectively. However, in China, the main NO_X emissions sources are industrial sources (including power plants and industrial production) and motor vehicles. As reported in the “Annual Report of Environmental Statistics” [11], NO_2 emission in 2014 in China was about 20.8 Mt, and the emissions from industrial source accounted for 67% and motor vehicle accounted for 30%. Urban life source only accounted for 3%.

Emissions of NO_X vary significantly by province owing to factors such as population, energy sources, and economic base. In China, NO_2 emission in Shandong province, Jiangsu province, Hebei province, and Guangdong province was the highest, which was related to large consumption of coal in these regions [9].

Figure 2.20 gives the annual variation tendency of NO_2 in the recent 3 years. It can be observed that NO_2 was decreasing during 2013–2015. The NO_2 concentrations in 2013 and 2014 were 44 μg/m^3 and 42 μg/m^3, respectively. It decreased to 39 μg/m^3 in 2015 and was lower than the CNAAQS grade II standard.

In 2015, the annual NO_2 concentrations in 338 cities were 8–63 μg/m^3 with an average of 30 μg/m^3. The average of NO_2 annual concentration did not exceeded the Chinese National Ambient Air Quality Standard and WHO AQG (40 μg/m^3). NO_2 concentrations at 81.7% of the monitoring cities were found to be lower than the CNAAQS (Fig. 2.21), and only 19.3% of the monitoring cities exceeded the CNAAQS. The number of days with NO_2 concentrations exceeding the CNAAQS occupied only 1.6% of all monitoring days.

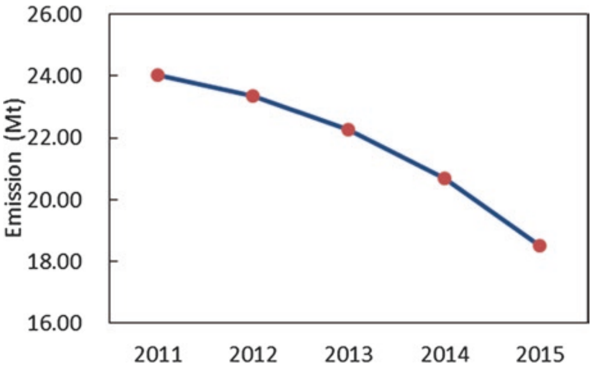


Fig. 2.19 Emission of NO_X in China from 2011 to 2015 (Data sources: MEP [9–13])

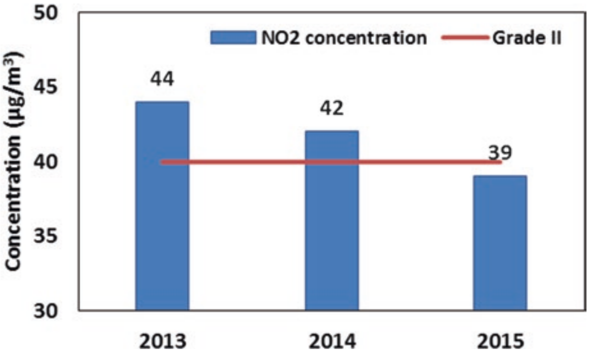


Fig. 2.20 Annual variation tendency of NO_2 in 74 key cities of China (Data sources: MEP [11–13])

Spatial distribution of NO_2 showed that the concentration in northern regions was higher than that in southern regions (Fig. 2.22). The NO_2 concentrations in North China, Pearl River Delta, and Urumqi City were the highest.

2.4 Conclusion

With the development of economy and industries, air pollution is getting more and more serious in China. Although reduced emissions have improved air quality in China, heavy pollution events occurred frequently.

$PM_{2.5}$ was the major pollutant in China. Although $PM_{2.5}$ annual concentration in China has decreasing trend, the CNAAQS limit value for $PM_{2.5}$ exceeded in large parts of China. The exceedances occurred in 77.5% of the case in all the monitoring cities in 2015. Beijing-Tianjin-Hebei region, the north and middle part of Shandong province, the south and middle part of Henan province, and most of Hubei province have higher $PM_{2.5}$ concentrations. The crustal elements and organic matter are major species of $PM_{2.5}$. Secondary particles formation and motor vehicle exhaust were the main sources of $PM_{2.5}$ in megacities.

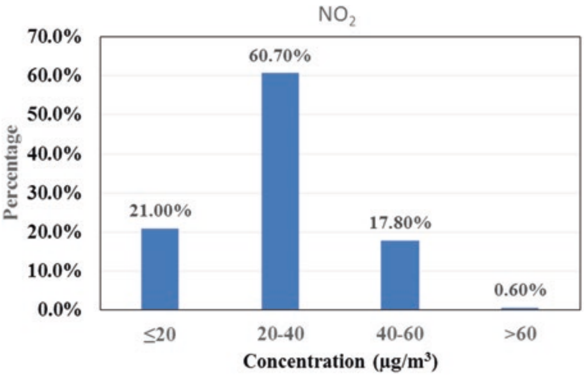


Fig. 2.21 Percentage of cities at different NO$_2$ concentration levels in 338 cities, 2015 (Data source: MEP [13])

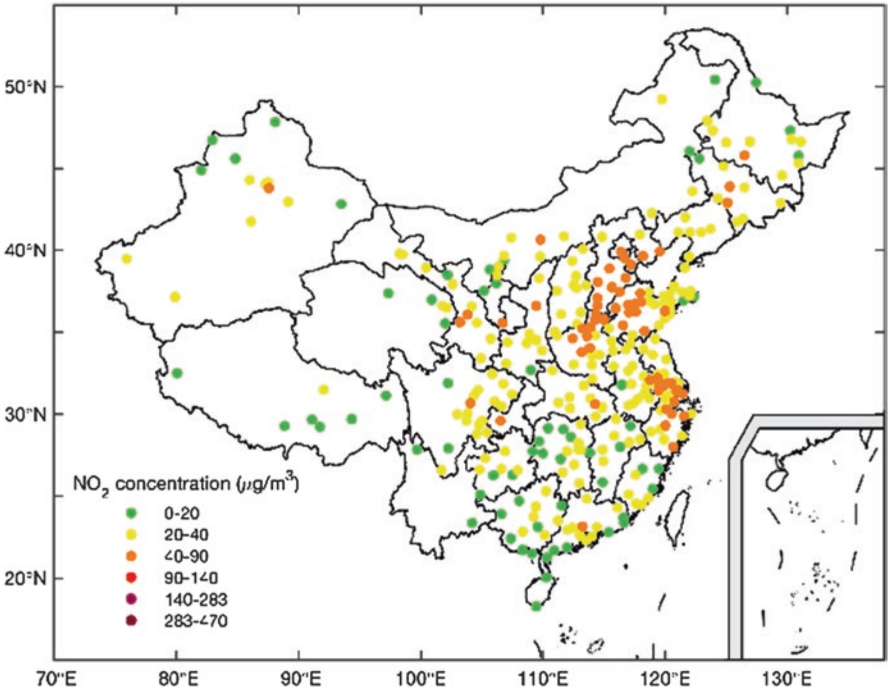


Fig. 2.22 Spatial distribution of NO$_2$ annual average concentrations in 2015 (Data sources: National air pollution monitoring network in China)

PM$_{10}$ also is an important pollutant in China. In 2015, PM$_{10}$ concentrations at 65.4% of the monitoring cities were found to be exceeded the CNAAQS. PM$_{10}$ annual concentration in the northern region was much higher than that in the southern region, which related to the influence of dust on northern cities. Soil dust was the first abundant component for PM$_{10}$ in most cities of China.

Although O_3 annual concentrations in the recent 3 years were lower than the CNAAQS, the average annual O_3 concentrations were increasing during 2013–2015. In 2015, the 90% of O_3 maximum daily 8-h mean concentrations in 338 cities were 62–203 μg/m^3 with an average of 134 μg/m^3. VOCs and NO_X emissions from motor vehicle was the major precursor gases of O_3 formation. The formation of O_3 is VOC-limited in urban areas of China and NO_X-limited in nonurban areas.

The average annual values of SO_2 for 74 key cities shows a decline trend in the recent 3 years, and all annual SO_2 concentrations stayed below the grade II standard value. NO_X also has decreasing trend and it decreased to 39 μg/m^3 in 2015, which was lower than the CNAAQS grade II standard. These results indicated that the measures taken to control SO_2 and NO_X pollution were effective.

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