Analysis of Air Pollution Trends in Beijing, China

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ABSTRACT

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Air pollution is a worldwide problem affecting not only the source location, but the globe as a whole. The current study aims to analyse the standard six air pollutants and air quality index (AQI) in Beijing, China. Air quality data was collected from 2014 to 2020 for temporal analysis. The average maximum values of the air pollutants and AQI during the period analysed were, PM_{2.5}: 74.4 µg/m³, PM₁₀: 107.3 µg/m³, SO₂: 20.7 µg/m³, CO: 1.5 mg/m³, NO₂: 56.3 µg/m³, O₃: 173.1 µg/m³ and AQI: 118. Maximum and minimum values of the primary pollutants occurred predominantly during winter and summer months, while O₃ exhibited an opposite trend. All air pollutants and AQI declined over the years. Significant reduction of over 50 % was archived for PM_{2.5}, PM₁₀, SO₂, CO and less than 5 % for O₃. The air pollution trend in Beijing has shown substantial improvement. In 2020, all air pollutants except PM_{2.5} achieved the national ambient air quality standard. This realisation can be credited to the effective policies implemented by the Chinese government.

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I. INTRODUCTION

Air pollution is a major problem in the world and industrialisation and economic development has resulted in indiscriminate release of various air pollutants into the atmosphere. Increasing air pollutants is directly linked to poor visibility, health problems affecting breathing, lungs, heart and others, and increase in global atmospheric temperature [1-3]. Recently scientists around the world have raised caution alarms on the deteriorating global air quality situation. Universally accepted measured five primary

pollutants are PM_{2.5}, PM₁₀, SO₂, CO and NO₂. The air quality index (AQI) is based on the five primary pollutants and O₃ which is a secondary pollutant. According to world air quality report in 2019 by IQAir, China stands eleventh and Beijing its capital ninth in the world for the highest average PM_{2.5} concentration [4]. Main industries in the region are heavy industries, metallurgy, chemicals and others [5]. Pollution in Beijing can be attributed to population growth, surge in motor vehicles, increase in industrial production, topography and seasonal weather [6]. Ambient air quality standards in China were

introduced in 2012 (GB 3095-2012) and the primary standards for urban areas are given in Table 1 [7]. Major PM_{2.5} sources in Beijing are motor vehicles, coal burning, industrial production and construction dust. The concentration of the primary pollutants has been found to decrease over the years [9]. Study by Han et al. [10] has shown that annual average PM_{2.5} concentration in Beijing declined by about 42 % from 2013 to 2017, resulting in the decline of respiratory and cardiovascular mortality by about 23 % and 34 %. In order to improve the air quality the Chinese government has taken measures such as reduction of sulphur dioxide and nitrogen oxides during the 11th and 12th five year plan periods. Air pollution prevention and control action plan was introduced in 2013 to reduce the particulate matter concentration in stages of 25 %, 20 %, and 15 % by 2017. Some of the important actions taken by the governing body to improve the air quality were, introduction of natural gas thermal power cogeneration in power plants, renovation of coal fired boilers and renovation of old one storey houses for efficient residential heating [9].

The current research work intends to study the changes in the prominent six air pollutants and AQI in Beijing municipality from 2014 to 2020. Objectives of the study were to identify the months and seasons with maximum impact from air pollutants and its current status.

Table 1: Chinese air pollution primary standards and WHO guidelines.

Pollutant	Averaging time	Chinese Standards 2012 [7]	WHO 2006 [8]
PM _{2.5}	24 hours	75	25
(µg/m ³)	annual	35	10
PM ₁₀	24 hours	150	50
(µg/m ³)	annual	70	20
O ₃ (µg/m ³)	8-hour	160	100

	maximum		
NO ₂ (µg/m ³)	24 hours	80	–
	annual	40	40
SO ₂ (µg/m ³)	24 hours	150	20
	annual	60	–
CO (mg/m ³)	24 hours	4	–

II. MATERIALS AND METHODS

Beijing municipality is situated at the north edge of the North China Plain and is the capital of China. It covers a total area of 16,800 km² with the population of 21.5 million [11,12]. The air pollution data for the Beijing municipality were obtained from aqistudy.cn website. The pollutants studied were PM_{2.5}, PM₁₀, SO₂, CO, NO₂, O₃ and AQI. Monthly average values were calculated using each day's hourly data. The data collected until 20th December 2020 was used in the analysis. It is anticipated that the influence caused by the data deficiency on the analysis would be minimal. The four seasons in the region considered in the study were spring (March, April and May), summer (June, July and August), autumn (September, October and November) and winter (December, January and February).

III. RESULTS AND DISCUSSION

Temporal Characteristics of Air Pollutants

A. Monthly Variation of Air Pollutants and AQI

The monthly average values of the air pollutants and AQI for seven years are presented in Figure 1. The changes exhibited by the primary pollutants were similar with maximum values occurring during the beginning and end of the year and minimum values during the middle of the year. Peak values of the air pollutants (PM_{2.5}, PM₁₀, SO₂, CO, NO₂, O₃) and AQI were 74.4 µg/m³, 107.3 µg/m³, 20.7 µg/m³, 1.5 mg/m³, 56.3 µg/m³, 173.1 µg/m³ and 118. Transition from high to low values generally occurred during March

until May and change from low to high values during October. The minimum values were during July and August, and May for CO. While the trend exhibited by O₃ and AQI were contrary when compared with the primary air pollutants, with high values occurring during the middle of the year (June) and low values during November and September. Similar trend was also observed by Zhao et al. [13]. These monthly variations indicate the contribution of climatic conditions in dispersing and removing air pollutants.

Figure 1: Monthly variation of air pollutants and AQI in Beijing.

B. Seasonal Variation of Air Pollutants and AQI

Seasonal variation of the prominent air pollutants and AQI are given in Figure 2. The maximum values of PM_{2.5}, SO₂, CO, NO₂ (73 µg/m³, 17.5 µg/m³, 1.4 mg/m³, 50.8 µg/m³) occurred in winter. This is predominantly caused due to heating sources used during winter in Beijing and seasonal climatic conditions with low wind speed and high relative humidity [13]. Maximum value of PM₁₀ (101.2 µg/m³) occurred during spring, this is because of the heating sources and wind erosion dust during spring [14]. O₃ concentration was highest during summer due to higher solar radiation and temperature which promotes photochemical activity suitable for O₃ formation [15]. AQI reached a maximum value during

summer, which may be attributed to high levels of O₃. The minimum values for PM_{2.5}, PM₁₀, SO₂, NO₂ and CO were during summer and spring. This decrease is predominantly caused by maximum precipitation during the summer months. One of the reasons for low values of CO during spring which extends through summer could be through photochemical degradation of CO [13]. The minimum value of O₃ occurred during winter season due to the lack of intense solar radiation. Minimum AQI value occurred during autumn. The fluctuations in the AQI values were minimal.

Figure 2: Seasonal variation of air pollutants and AQI in Beijing.

C. Annual variation of Air Pollutants and AQI

The annual values of the pollutants and AQI are given in Figure 3. It can be seen that all air pollutants and AQI have shown a decreasing trend over the years. The percentage reduction achieved for PM_{2.5}, PM₁₀, SO₂, NO₂, CO, O₃ and AQI were 55.6, 51.9, 82.3, 46.8, 50.8, 4.2 and 37.7. Maximum reduction was achieved for SO₂ and minimum for O₃. This can be directly linked to the policies and actions taken by the central administration and local governing bodies. In 2020, the PM_{2.5} was 2.7 µg/m³ greater than the annual Chinese standard. However, PM₁₀, SO₂, CO, NO₂ and O₃ decreased by 13.9 µg/m³, 56.3 µg/m³, 3.4 mg/m³,

10.8 $\mu\text{g}/\text{m}^3$ and 65.1 $\mu\text{g}/\text{m}^3$ and conformed to the 2012 Chinese standards [7]. Similar decreasing trend was also reported by Tian et al. [16]. When compared with the WHO standards $\text{PM}_{2.5}$ and PM_{10} were 27.7 $\mu\text{g}/\text{m}^3$ and 36.1 $\mu\text{g}/\text{m}^3$ greater, while NO_2 and O_3 were 10.8 $\mu\text{g}/\text{m}^3$ and 5.1 $\mu\text{g}/\text{m}^3$ lower and comply with the 2006 WHO standards. It should also be borne in mind that lockdown measures taken because of the COVID-19 pandemic would have also contributed to the decline in the air pollution during 2020. The decreasing trend of the air pollutants and AQI is a positive sign and further measures could make Beijing comparable with world cities with clean air.

Figure 3: Annual variation of air pollutants and AQI in Beijing.

IV. CONCLUSION

The comprehensive study of the air pollution and AQI data in Beijing was successfully conducted for the period 2014 – 2020. The study indicated high concentration of air pollutants in the atmosphere during the year beginning and end (late autumn to winter) and low during middle of the year in summer. Exceptions were observed for maximum PM_{10} and minimum CO concentrations which occurred during spring. Opposite trend was exhibited by O_3 and AQI with high values during summer and low values in

winter and autumn. All air pollutant concentrations and AQI showed a decreasing trend with maximum reduction archived for SO_2 (82.3 %) and minimum for O_3 (4.2 %). New technological developments and stringent regulation could further improve the air quality.

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