Spatiotemporal Variation of Ozone Concentration and Its Influencing Factors in Inner Mongolia in Recent Three Years: Postprint

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Date: 2019-09-11T00:00:00+00:00

Abstract

To scientifically characterize ozone (O3) pollution features and their influencing factors in the Inner Mongolia region, data from nationally-controlled environmental monitoring stations and national meteorological stations across 12 leagues and cities in Inner Mongolia from 2015 to 2017 were analyzed. The results show that: compared with 2015, both O3 concentration and pollution severity exhibited an overall worsening trend in 2017; O3 concentrations were highest from May to August, with the most severe pollution occurring during this period and peaking in July. In terms of spatial variation, O3 pollution concentrations were relatively high in the central and western regions of Inner Mongolia and relatively low in the eastern regions, demonstrating a certain degree of correlation with the economic development level of Inner Mongolia. Particulate matter, precursor substances, and meteorological factors all represent important factors influencing O3 concentration, among which PM2.5, CO, and NO2 all displayed significant negative correlations with O3 concentration, while O3 concentration gradually decreased with increasing relative humidity.

Full Text

Spatiotemporal Variation of Ozone Concentration and Its Influential Factors in Inner Mongolia in Recent 3 Years

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Abstract: To study ozone pollution in Inner Mongolia and its influential factors, data from national environmental monitoring stations and national meteorological stations in 12 cities in Inner Mongolia from 2015 to 2017 were ana-

lyzed. The overall ozone pollution in 2017 was aggravated compared with that in 2015, and the ozone concentration was the highest and most serious during the period from May to August, especially in July. Spatially, ozone pollution was relatively more serious in the central and western parts of Inner Mongolia, while lower in the eastern parts, which was synchronous with the economic development level. Particles, precursors, and meteorological factors were the important factors affecting ozone concentration. There were significantly negative correlations between the ozone concentration and PM2.5, CO, and NO2, and the ozone concentration decreased gradually with the increase of relative humidity.

Keywords: ozone concentration; particulate matter; spatiotemporal variation; relative humidity; Inner Mongolia

1 Introduction

1.1 Research Background

Ozone pollution has become increasingly prominent in recent years. Previous studies have analyzed ozone characteristics in various regions [7-14], but research specifically focused on Inner Mongolia remains limited. The available studies indicate that ozone formation is influenced by complex interactions between meteorological conditions, precursor emissions, and particulate matter concentrations. Understanding these relationships is crucial for developing effective air quality management strategies in arid and semi-arid regions.

2 Data and Methods

The analysis utilized monitoring data for PM2.5, PM10, CO, NO2, and O3 from 12 cities in Inner Mongolia covering the period 2015-2017. Data were obtained from the national environmental monitoring network (http://106.37.208.233:20035/) and national meteorological stations. The evaluation followed the *Ambient Air Quality Standards* (HJ663-2013) [16].

For ozone metrics, the 8-hour moving average concentration (O3-8h) was calculated, and the 90th percentile (O3-8h-90) was determined for each city as the primary indicator. The monitoring period spanned 342-366 days annually. In 2015, the O3-8h-90 values ranged from 104 to 153 $g \cdot m^{3}$, with an average of 135 $g \cdot m^{3}$. The national standard exceedance rate was 2.2% in 2015, increasing to 3.9% by 2017. The maximum recorded O3-8h-90 value was 153 $g \cdot m^{3}$, observed in July.

Table 1 Meteorological conditions and O3 concentration in Inner Mongolia during the period of 2015-2017

[Figure 1: see original paper]

Fig. 1 O3-8h-90 in the cities in Inner Mongolia during the period of 2015-2017

2.1 Temporal Variation Characteristics

2.1.1 Inter-annual Variation Ozone concentrations showed significant year-to-year variation. The O3-8h-90 values were higher in 2017 compared to 2015, indicating worsening ozone pollution. The most severe ozone episodes occurred during summer months, particularly July, when photochemical production is most active.

2.1.2 Seasonal Variation Ozone concentrations exhibited pronounced seasonal patterns, with elevated levels during May through August and peak concentrations in July (averaging 131 $g \cdot m^{3}$). Conversely, the lowest concentrations occurred in December (averaging 55 $g \cdot m^{3}$). This seasonal cycle reflects the combined influence of solar radiation intensity, temperature, and photochemical reaction rates. During summer months (May-August), high temperatures and strong solar radiation promote ozone formation, while winter conditions suppress photochemical activity.

The seasonal pattern also correlates with meteorological factors including temperature, solar radiation, and precipitation. The summer monsoon period brings conditions favorable for ozone accumulation, while increased wintertime mixing depths and reduced photochemical activity result in lower concentrations.

2.2 Spatial Distribution Characteristics

Spatial analysis using ArcGIS revealed distinct regional patterns in ozone concentrations across Inner Mongolia. The central and western regions exhibited higher ozone levels compared to the eastern areas. This spatial gradient aligns with economic development patterns and emission source distributions. The O3-8h values showed significant spatial heterogeneity, with pollution hotspots concentrated in urban-industrial clusters.

[Figure 2: see original paper]

Fig. 2 Spatial distribution of O3-8h in Inner Mongolia (2015-2017)

[Figure 3: see original paper]

Fig. 3 Spatial distribution of O3-8h-90 in Inner Mongolia (2015-2017)

The spatial distribution of ozone is influenced by multiple factors including precursor emissions, meteorological transport, and regional topography. Central and western cities, with more intensive industrial activities and higher vehicle emissions, showed elevated ozone levels. Eastern regions, characterized by lower emission densities and different meteorological regimes, experienced relatively lower ozone concentrations.

2.3 Relationship Between O3 and Meteorological Factors

Statistical analysis revealed significant correlations between ozone concentrations and meteorological parameters. Temperature showed a positive correla-

tion with ozone, with correlation coefficients between 0.814 and 0.289 ($P < 0.01$), indicating that higher temperatures favor ozone formation. However, the relationship with particulate matter was inverse.

2.3.1 Temperature Effects Ozone concentrations increased with rising temperatures, particularly during summer months when temperatures exceed 25°C. The correlation between temperature and ozone was statistically significant ($P < 0.01$), consistent with the temperature dependence of photochemical reaction rates.

2.3.2 Humidity Effects Relative humidity (RH) demonstrated a significant negative correlation with ozone concentration. When RH was below 40%, the average ozone concentration reached 99.33 $g \cdot m^{3}$, with the highest exceedance rates. As humidity increased, ozone concentrations decreased progressively. At RH 90%, ozone levels dropped substantially due to enhanced deposition and reduced photochemical efficiency.

Table 2 Overstandard rate of O3 and average concentration in different relative humidity (RH) levels

The negative correlation between ozone and humidity is attributed to several mechanisms: (1) water vapor can act as a sink for ozone precursors; (2) high humidity often accompanies cloud cover, reducing solar radiation; and (3) moisture affects the partitioning of chemical species in the atmosphere. Studies have shown that at RH < 60%, ozone formation is primarily limited by precursor availability, while at RH > 60%, meteorological dispersion becomes the dominant factor [24].

2.4 Relationship Between O3 and Air Pollutants

Ozone concentrations showed significantly negative correlations with PM2.5, CO, and NO2 concentrations ($P < 0.01$). The correlation coefficients ranged from -0.906 to -0.954, indicating strong inverse relationships. This pattern suggests complex interactions between ozone and other pollutants:

1. **PM2.5 and O3**: The negative correlation may reflect: (a) PM2.5 particles can scavenge ozone precursors and radicals; (b) high PM2.5 episodes often occur under meteorological conditions unfavorable for ozone formation; (c) the titration effect of NO in high NOx environments [19-21].
2. **NO2 and O3**: The inverse relationship results from the photochemical equilibrium between NO, NO2, and O3. High NO2 concentrations often indicate fresh emissions and NO titration effects that reduce ozone levels, particularly in urban areas [14].
3. **CO and O3**: The negative correlation with CO, a primary pollutant, suggests that high CO concentrations coincide with conditions that sup-

press ozone formation or that CO measurements serve as an indicator of emission source proximity.

The analysis indicates that while ozone is a secondary pollutant formed from precursor emissions, its concentration patterns are inversely related to primary pollutant concentrations under certain conditions. This paradox highlights the non-linear nature of atmospheric photochemistry and the importance of meteorological context in determining ozone levels.

3 Conclusion

The study of ozone pollution in Inner Mongolia from 2015-2017 reveals: 1. Worsening ozone pollution, with 2017 showing higher concentrations than 2015 2. Distinct seasonal patterns with summer peaks (May-August, especially July) 3. Spatial heterogeneity, with higher levels in central/western regions correlating with economic activity 4. Significant negative correlations with relative humidity and primary pollutants (PM2.5, CO, NO2)

These findings underscore the need for integrated air quality management strategies that account for the complex interactions between meteorology, emissions, and atmospheric chemistry in arid and semi-arid environments.

Note: Figure translations are in progress. See original paper for figures.