# Variation Characteristics of Atmospheric Environmental Capacity and Its Influencing Factors in Ningxia over the Past 60 Years: Postprint

**Authors:** Cui Yang1,2, Wang Dai[1],[2], Gao Ruina^{1,2}, An Xingqin 3

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## Abstract

To investigate variations in atmospheric environmental capacity and its influencing factors in Ningxia, daily historical observational data from meteorological stations during 1961–2018 were utilized. Based on the box model principle, the spatiotemporal distribution of atmospheric environmental capacity A values (the total pollutant emission control coefficient) in Ningxia and its primary meteorological influencing factors were analyzed, and a zoning assessment of atmospheric environmental capacity for 2018 was conducted. The results indicate that the atmospheric environmental capacity A values in Ningxia exhibit an overall decreasing trend across all seasons, with a rate of -0.47$\times10^{4}$ to -0.24$\times10^{4}$ km$^{2}\cdot(10a)^{-1}$. Among the seasons, A values are highest in summer, followed by spring, and lower in autumn and winter. Monthly A values show a unimodal variation pattern, with the maximum in August and the minimum in December, and spatially exhibit a distribution characteristic of high values in the south and low values in the north. Influenced by factors such as the topography of the Helan Mountains and Liupan Mountains and regional precipitation, the low-value center of A is located in Yinchuan City and Shizuishan City, while the high-value center is situated in the southern region of Guyuan City. Variations in wind speed and mixing layer height exert a decisive influence on the interdecadal evolution trend of atmospheric environmental capacity A values in Ningxia; the influences of precipitation and wind speed show significant seasonal and regional differences, with wind speed contributing substantially to A values in spring in the northern region, and precipitation contributing substantially to A values in summer and autumn in the central and southern regions. Affected by emissions from energy-intensive industries such as metallurgy, thermal power, chemical engineering, and construction, as well as vehicle emissions, Pingluo County and Litong District are classified as critical and below-critical carrying zones for atmospheric environment $SO_2$ and

NO  in Ningxia, while areas south of Litong District are high carrying capacity zones.

## Full Text

## Abstract

This study investigates the variation characteristics of atmospheric environmental capacity and its influencing factors in Ningxia. Using daily historical observation data from meteorological stations spanning 1961–2018, we analyzed the spatiotemporal distribution of the atmospheric environmental capacity coefficient A (pollutant emission total control coefficient) and its primary meteorological driving factors based on box model principles, and conducted a zoning assessment of atmospheric environmental capacity. The results indicate that the A value in Ningxia exhibited an overall decreasing trend across all seasons, with rates of $-0.47\$\times10^{\{4\}\cdot(10a)}\{\text{-1}\}, -0.46\times10^{\{4\}\cdot(10a)}\{\text{-1}\}, -0.33\times10^{\{4\}\cdot(10a)}\{\text{-1}\}, and - 0.24\times10^{\{4\}\cdot(10a)}\{\text{-1}\}\$$ for spring, summer, autumn, and winter, respectively, with the most significant declines occurring in autumn and winter. Spatially, the A value demonstrated a pattern of higher values in the south and lower values in the north. Influenced by the topography of Helan Mountain and Liupan Mountain, as well as regional precipitation patterns, low-value centers were located in Yinchuan and Shizuishan cities, while high-value centers were situated in southern Guyuan. Seasonally, the A value was highest in summer, followed by spring, with lower values in autumn and winter. Monthly A values displayed a unimodal pattern, peaking in July and reaching a minimum in December. Wind speed and mixed layer height variations exerted a decisive influence on the interdecadal evolution of the A value, while precipitation and wind speed impacts showed clear seasonal and regional differences—wind speed contributed significantly to spring A values in northern regions, whereas precipitation contributed substantially to summer and autumn A values in central and southern areas. Affected by high-energy-consumption industries such as metallurgy, thermal power, chemical production, and construction, as well as vehicle emissions, Pingluo County and Litong District were identified as critical overload and overload zones for atmospheric environmental capacity, while areas south of Litong District represented high-capacity zones.

**Keywords:** atmospheric environmental capacity; atmospheric environmental carrying capacity index; meteorological influence factors; remaining capacity; Ningxia

## Introduction

With rapid economic and social development, the consumption of coal, petroleum, natural gas, and other energy sources has continuously increased, making atmospheric environmental quality a focal concern for the public in China. Research on atmospheric environmental capacity forms the foundation for scientifically establishing regional atmospheric pollution total control targets, rationally utilizing limited atmospheric environmental capacity resources, and improving air quality. Since Japan first proposed the concept of atmospheric environmental capacity in the 1960s to address environmental pollution problems [?], countries including Canada [?], India [?], and Turkey [?] have applied it to atmospheric pollution research, environmental quality standard formulation, and pollution prevention studies, providing fundamental support for environmental management departments to develop scientific air pollution control policies. China began researching atmospheric environmental capacity in the late 1970s [?], achieving numerous research outcomes. Xu Dahai et al. [?, ?] defined atmospheric environmental capacity using box model theory as the balance between pollutant generation and removal within a given air volume and time period at a specified average concentration level. An Xingqin et al. [?] simulated concentration distributions and source contributions for each pollution unit through numerical modeling. Sun Wenjie [?] introduced environmental variation terms reflecting pollutant dynamic changes into atmospheric environmental capacity research. Zhu Rong et al. [?] developed a calculation method for atmospheric self-purification capacity indices based on conventional meteorological observations, reflecting the atmosphere's ventilation dilution and wet removal capabilities for pollutants. In essence, atmospheric environmental capacity represents the maximum amount of atmospheric pollutants that a region's environment can accommodate during a specific period. It provides an objective quantitative characterization of the atmosphere's pollutant-carrying capacity—smaller capacity indicates poorer pollutant removal capability, and vice versa.

Atmospheric environmental capacity is not only related to pollutant emissions but also closely associated with meteorological conditions. Meteorological factors primarily influence capacity through pollutant transport and diffusion, dry and wet deposition, and various chemical removal and transformation processes. Boundary layer inversions facilitate severe haze formation and intensification [?, ?], as strong inversions and low boundary layer heights inhibit sufficient development of near-surface turbulence, hindering pollutant dispersion [?]. Local conditions of high temperature, high humidity, and weak winds during autumn and winter contribute to severe pollution events in cities like Huaian [?] and Changzhou [?]. When the 500 hPa level is under a northwest-westerly flow ahead of a high-pressure ridge and the surface is in a weak high or low pressure field, Langfang City is prone to continuous heavy pollution events [?]. Low temperatures, weak winds, high relative humidity, and inversion weather constitute important causes of severe particulate pollution during the heating period in Urumqi [?]. Precipitation wet removal effectively eliminates pollutants, while wind speed directly affects pollutant diffusion rates [?]. Declining atmospheric environmental carrying capacity represents a primary cause of regional air quality deterioration.

Since the 21st century, pollutant emissions have increased across Ningxia, with atmospheric environmental quality noticeably declining. Due to the absence of research on atmospheric environmental capacity changes, pollution prevention measures have proven generally ineffective. Meanwhile, under global climate change, the spatiotemporal distribution patterns of meteorological factors such as precipitation and wind speed in Ningxia have also undergone significant changes. Therefore, this study utilizes historical meteorological and environmental quality data to calculate the atmospheric environmental capacity A value, analyze its spatiotemporal variation characteristics, investigate the influence of meteorological factors on the A value, and explore changes in atmospheric pollutant carrying capacity, aiming to provide scientific support for the construction of an ecological protection and high-quality development pilot zone in the Yellow River Basin.

## 1 Data and Methods

### 1.1 Data Sources

Based on data continuity and completeness, we selected regular observation data from 23 meteorological stations in Ningxia for 1961–2018, including cloud cover (total and low cloud), wind speed, and precipitation. For atmospheric environmental capacity parameter calculations, wind speed and cloud cover data were extracted at 02:00, 08:00, 14:00, and 20:00 daily, while precipitation data were monthly totals. Pollutant concentration data comprised daily observations from environmental quality monitoring stations in five prefecture-level city urban areas, and atmospheric pollutant emission data were obtained from the *Ningxia Statistical Yearbook (2019).*

### 1.2 Calculation Methods

**1.2.1 Atmospheric Environmental Capacity** According to the estimation method for atmospheric pollutant total emissions in *Technical Methods for Formulating Local Air Pollutant Emission Standards* (GB/T 3840-91) and research by Xu Dahai et al. [**?**], atmospheric environmental capacity under long-term equilibrium conditions is typically expressed as:

$$A = \frac{S \cdot C_S}{T}$$

where $A$ represents the pollutant emission total control coefficient, $S$ denotes the total area of the control zone, $C_S$ indicates the pollutant standard concentration limit, and $T$ is the time period. In this formula, $S$ is constant for each region and $C_S$ is a fixed value. Therefore, without considering regional pollutant concentration changes, the variability of atmospheric environmental capacity primarily depends on the pollutant emission total control coefficient $A$, meaning that changes in $A$ can reflect variations in atmospheric environmental capacity.

To analyze the spatiotemporal variation characteristics of atmospheric environmental capacity across regions, the specific calculation method for the $A$ value is given as:

$$A = 3.1536 \times 10^7 \cdot V_E \cdot W_r \cdot R \cdot S$$

where $V_E$ represents ventilation volume ($10^4$ km$^2 \cdot$ s$^{-1}$), $W_r$ denotes the washout ratio (1.9$×10^{-5}$), $R$ indicates precipitation rate (mm $\cdot$ s$^{-1}$), and $S$ is the area (km$^2$).

**1.2.2 Ventilation Volume** Ventilation volume characterizes boundary layer atmospheric motion states [?]. Theoretically, instantaneous ventilation volume $V_E'$ is obtained by integrating wind speed from the surface to the mixed layer top height:

$$V_E' = \int_0^{H_i} u_i(z)\,dz + \int_{200}^{H_i} u_i(z)\,dz$$

where $z$ represents height above ground (m), $H_i$ denotes mixed layer height (m), and $u_i(z)$ indicates average wind speed at height $z$ (m $\cdot$ s$^{-1}$). In practical research, $V_E'$ is generally calculated using wind speed at 10 m height ($u_{10}$) and the wind speed height exponent $p$. During calculation, when $u_{10} \leq 6$ m $\cdot$ s$^{-1}$, the actual wind speed value is used; when $u_{10} > 6$ m $\cdot$ s$^{-1}$, the value is set to 6 m $\cdot$ s$^{-1}$. The $p$ value is determined according to atmospheric stability [?]. Based on the *Handbook on the Total Quantity Control of Urban Air Pollution* [?], monthly and seasonal ventilation volumes $V_E$ were calculated using hourly ventilation volumes $V_E'$.

**1.2.3 Atmospheric Environmental Carrying Capacity Index** Using regional pollutant concentration observation data, we conducted rationality analysis of atmospheric environmental capacity. Following the technical methods for evaluating resource-environment carrying capacity and territorial space development suitability [?], the atmospheric environmental carrying capacity index for each region was calculated using:

$$P_i = \frac{E_i - Q_i}{Q_i}$$

where $P_i$ represents the atmospheric environmental carrying capacity index, $E_i$ denotes emissions of pollutant $i$, and $Q_i$ indicates environmental capacity for pollutant $i$. Lower index values correspond to greater atmospheric environmental capacity.

Referencing the classification method of Liu Longhua et al. [?] and considering Ningxia's climatic and environmental characteristics, atmospheric environmental carrying capacity was classified into five levels: severe overload ($P_i > 0$), overload ($-0.4 < P_i \leq 0$), critical overload ($-0.7 < P_i \leq -0.4$), medium capacity ($-1.0 < P_i \leq -0.7$), and high capacity ($P_i \leq -1.0$).

# 2 Results

## 2.1 Spatiotemporal Distribution Characteristics of Atmospheric Environmental Capacity

The monthly average atmospheric environmental capacity coefficient $A$ in Ningxia was $1.0\$\times 10^{\{4\}-6.5\times 10}\{4\}\$$ km$^2 \cdot$ s$^{-1}$, showing a unimodal pattern with maximum values in summer (July) and minimum values in winter (December) [Figure 2: see original paper]. Monthly $A$ values peaked in July and reached minima in December across all cities. The annual average $A$ values were $6.2\$\times 10^{\{4\},4.0\times 10}\{4\},3.5\times 10^{\{4\},2.4\times 10}\{4\},and 1.1\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$ for Guyuan, Zhongwei, Wuzhong, Shizuishan, and Yinchuan, respectively, with Guyuan showing the highest and Yinchuan the lowest values.

Interannual variations in seasonal $A$ values were pronounced. The multi-year average was highest in summer ($4.7\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$), followed by spring ($3.0\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$), with lower values in autumn ($2.3\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$) and winter ($1.1\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$) [Figure 3: see original paper]. All seasons showed decreasing trends, with rates of $-0.47\$\times 10^{\{4\},-0.46\times 10}\{4\},-0.33\times 10^{\{4\},and-0.24\times 10}\{4\}\$$ km$^2 \cdot$ s$^{-1} \cdot$ (10a)$^{-1}$ for spring, summer, autumn, and winter, respectively, all significant at the $P \leq 0.05$ level. Notable differences existed in interdecadal variations: spring, summer, and winter showed "increase–decrease–increase" patterns, while autumn consistently decreased. A sharp decline occurred after 1969, followed by slight increases.

Spatially, spring $A$ values ranged from $1.8\$\times 10\hat{}\{4\}\$$ to $4.3\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$, with values below $2.4\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$ in northern Yinchuan and Xiji, and above $3.0\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$ in southern Guyuan. All regions showed significant decreasing trends, with the most pronounced declines in Huinong, Zhongwei, Zhongning, Tongxin, and Haiyuan [Figure 4: see original paper]. Summer $A$ values varied considerably, ranging from $2.1\$\times 10\hat{}\{4\}\$$ to $8.0\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$, with Haiyuan and Guyuan showing the highest values. Autumn values were below $1.5\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$ in Shizuishan and Yinchuan (forming low-value centers), while most other areas ranged from $1.6\$\times 10\hat{}\{4\}\$$ to $3.5\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$, with Haiyuan and southern Guyuan as high-value centers. All regions exhibited decreasing trends from $-0.15\$\times 10\hat{}\{4\}\$$ to $-0.79\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1} \cdot$ (10a)$^{-1}$, with the largest decline in Haiyuan. Winter $A$ values showed smaller regional differences, mostly below $2.1\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1}$, with decreasing trends ranging from $-0.17\$\times 10\hat{}\{4\}\$$ to $-0.72\$\times 10\hat{}\{4\}\$$ km$^2 \cdot$ s$^{-1} \cdot$ (10a)$^{-1}$, particularly pronounced in Yanchi, Haiyuan, and Guyuan.

## 2.2 Analysis of Meteorological Factors Influencing Atmospheric Environmental Capacity

The calculation formula shows that transport-diffusion removal terms and wet deposition removal terms are the primary determinants of atmospheric environmental capacity. The transport-diffusion term is represented by ventilation volume calculated from wind speed and mixed layer height—higher wind speeds and mixed layer heights enhance turbulent diffusion of pollutants, while precipitation provides scavenging and wet deposition effects.

To investigate meteorological influences on spatiotemporal variations of atmospheric environmental capacity, we analyzed the characteristics of mean wind speed, mixed layer height, and precipitation, and their relationships with the $A$ value. Mean wind speed in Ningxia showed an overall decreasing trend with distinct interdecadal phases: seasonal average wind speed increased from 1961–1969, decreased sharply after 1969, and increased again after 2000 [Figure 5: see original paper], consistent with $A$ value variations and indicating a decisive influence on interdecadal evolution. Mixed layer height showed a gradual increasing trend before 1969 in spring and summer, followed by slight decreases; autumn and winter showed weak decreasing trends before 1969, then decreasing-increasing patterns [Figure 5: see original paper], suggesting that its interdecadal fluctuations significantly affected $A$ values. Summer precipitation was highest with large interannual variability, while spring and autumn precipitation showed moderate amounts and variability, and winter precipitation was minimal with no significant interannual variation, indicating that precipitation had no significant influence on interdecadal $A$ value changes.

Regional differences in meteorological factor influences were evident. Wind speeds were higher in spring and winter and lower in summer and autumn. Huinong, Zhongning, Tongxin, and Haiyuan had relatively high wind speeds, while Yinchuan, Wuzhong, and Xiji had lower speeds [Figure 6: see original paper]. Wind speed showed the highest correlation with $A$ values in spring and winter, with significant positive relationships (passing $P \leq 0.05$ significance tests) in most areas. Significant correlations existed year-round in Shizuishan, Taole, Wuzhong, and Zhongning, but only in spring and winter in Yanchi, Haiyuan, Xiji, and Guyuan, demonstrating clear seasonal and regional differences in wind speed impacts.

Mixed layer heights were higher in spring and summer and lower in autumn and winter [Figure 6: see original paper], with significant positive correlations with $A$ values in all seasons (passing $P \leq 0.01$ significance tests). This indicates substantial seasonal influence—higher mixed layer heights corresponded to larger $A$ values. Summer precipitation accounted for approximately 55% of annual totals, decreasing from south to north spatially [Figure 6: see original paper]. Correlation coefficients between precipitation and $A$ values showed significant seasonal and spatial variations: northern regions (Huinong, Yinchuan, Wuzhong) showed significant correlations only in summer, while central-southern regions (Yanchi, Tongxin, Haiyuan, Guyuan, Xiji) showed significant correlations in spring, summer, and autumn [Figure 6: see original paper]. Precipitation contributed more to $A$ values in summer in northern arid regions and in spring, summer, and autumn in central-southern regions.

Contribution rate analysis revealed that in spring and autumn, wind speed and mixed layer height contributed 40–70% to $A$ values in Wuzhong, Yinchuan, and Shizuishan, indicating that atmospheric turbulent transport-diffusion was the dominant factor for northern regions. In central-southern regions, precipitation contribution rates in Yanchi, Tongxin, and Xiji exceeded those of wind speed in spring, suggesting that mixed layer height and precipitation were key determinants of spring $A$ values there. In summer, mixed layer height contributed most to $A$ values in northern regions, with precipitation and wind speed contributing similarly; in central-southern regions, mixed layer height and precipitation contributed substantially, with precipitation accounting for nearly half or more of the contribution in Yanchi, Tongxin, Xiji, and Guyuan [Figure 7: see original paper]. In winter, the contribution ranking was mixed layer height > wind speed > precipitation across Ningxia.

### 2.3 Rationality Analysis and Remaining Capacity Estimation

According to *Ambient Air Quality Standards* (GB3095–2012) secondary standards, we evaluated the rationality of calculated atmospheric environmental capacity and estimated remaining capacity. In 2018, urban $SO_2$ concentrations at five city monitoring stations averaged 0.009–0.041 $mg \cdot m^{-3}$, not exceeding the secondary standard limit of 0.06 $mg \cdot m^{-3}$, indicating remaining environmental capacity. NOx concentrations ranged from 0.02 to 0.054 $mg \cdot m^{-3}$, also meeting standard requirements, confirming the rationality of calculated atmospheric environmental capacity. The negative remaining capacity value for Shizuishan (due to missing cloud observations at Dawukou Station after 2000) was considered reasonable.

Remaining capacity varied significantly across cities: Guyuan had the largest remaining capacity at 9.20$×10^{4}$ t, while Yinchuan had the smallest at 0.69$×10^{4}$ t . Based on atmospheric environmental carrying capacity zoning results [Figure 8: see original paper], Pingluo County and Litong District were classified as critically overloaded for both $SO_2$ and NOx in 2018, while Yinchuan urban area showed medium capacity. For the period 2016–2018, Huinong District was critically overloaded, Pingluo County and Litong District showed medium capacity, and all other areas demonstrated high capacity. High-energy-consumption industries (metallurgy, thermal power, chemical production, construction) and vehicle emissions with large total amounts and high intensities were the main causes of overload and critical overload in these counties and districts. Areas south of Litong District exhibited high atmospheric environmental capacity.

To further improve overall atmospheric environmental quality in Ningxia, Huinong District should reduce $SO_2$ emissions by more than 0.63$×10^{4}$ t and control new emissions below 0.16$×10^{4}$ t. New emissions in Pingluo County and Litong District should be limited to 0.50$×10^{4}$ t and 0.23$×10^{4}$ t, respectively. If these reductions and controls are implemented, and other regions maintain emissions within remaining capacity limits, Ningxia will temporarily avoid overload conditions.

## 3 Conclusions

1) The atmospheric environmental capacity coefficient A in Ningxia showed an overall decreasing trend across all four seasons from 1961–2018, with rates of −0.47$×10^{{4}, −0.46×10}{4}, −0.33×10^{{4}, and − 0.24×10}{4}$ km$^2$ · s$^{-1}$ · (10a)$^{-1}$ for spring, summer, autumn, and winter, respectively, with autumn and winter showing the most significant declines. Seasonally, A values were highest in summer (4.7$×10^{4}$ km$^2$ · s$^{-1}$), followed by spring (3.0$×10^{4}$ km$^2$ · s$^{-1}$), with lower values in autumn (2.3$×10^{4}$ km$^2$ · s$^{-1}$) and winter (1.1$×10^{4}$ km$^2$ · s$^{-1}$). Spatially, A values exhibited a pattern of higher values in the south and lower values in the north, with seasonal ranges of 1.8$×10^{{4}−4.3×10}{4}$ km$^2$ · s$^{-1}$ in spring, 2.1$×10^{{4}−8.0×10}{4}$ km$^2$ · s$^{-1}$ in summer, 1.1$×10^{{4}−3.5×10}{4}$ km$^2$ · s$^{-1}$ in autumn, and 0.7$×10^{{4}−2.1×10}{4}$ km$^2$ · s$^{-1}$ in winter. Influenced by Helan Mountain and Liupan Mountain topography and regional precipitation, low-value centers were located in Yinchuan and Shizuishan, while high-value centers were in southern Guyuan.

2) Wind speed and mixed layer height variations decisively influenced the interdecadal evolution of the A value, while precipitation affected its interannual variability. Most regions showed significant positive correlations between A values and mixed layer height. Precipitation and wind speed impacts displayed clear seasonal and regional differences: wind speed contributed substantially to spring A values in northern areas, while precipitation contributed significantly to summer and autumn A values in central and southern regions.

3) In 2018, Ningxia's urban $SO_2$ and NOx emissions were 0.54$×10^{4}$ t and 3.73$×10^{4}$ t, respectively, with remaining capacities of 0.69$×10^{{4}−9.20×10}{4}$ t and 0.13$×10^{{4}−8.24×10}{4}$ t. Guyuan had the largest remaining capacity, while Yinchuan had the smallest. Due to impacts from high-energy-consumption industries (metallurgy, thermal power, chemical production, construction) and vehicle emissions, Pingluo County and Litong District were identified as critical overload and overload zones, while areas south of Litong District were high-capacity zones.

4) To further improve Ningxia's atmospheric environmental quality, Huinong District should reduce $SO_2$ emissions by more than 0.63$×10^{4}$ t and limit new emissions to 0.16$×10^{4}$ t. New emissions in Pingluo

County and Litong District should be controlled below 0.50$×10^{4}$ t and 0.23$×10^{4}$ t, respectively, while other regions should limit new emissions to 0.17$×10^{4}$ t for $SO_2$ and 1.47$×10^{4}$ t for NOx. If these measures are implemented, Ningxia will temporarily avoid overload conditions.

## References

[?] Lui Hongliang, Liao Tiancheng, Yang Benjin, et al. Environmental capacity and background value investigation report of the investigation mission to Japan [?]. Trends in Environmental Science, 1983(Suppl. 2): 1-8.

[?] Karen M M, Lawrence C, Marvin P O, et al. A comparison of box and plume model calculations for sulphur deposition and flux in Alberta, Canada[?]. Atmospheric Environment, 1996, 30(17): 2969-2980.

[?] Goyal S K, Chalapati Rao C V. Air assimilative capacitybased environment friendly siting of new industries A case study of Kochi region, India[?]. Journal of Environmental Management, 2007, 84(4): 473-483.

[?] Gene D D, Yesilyurt C, Tuncel G. Air pollution forecasting in Ankara, Turkey using air pollution index and its relation to assimilative capacity of the atmosphere[?]. Environmental Monitoring and Assessment, 2010, 166(1-4): 11-27.

[?] Ritter M, Müller M D, Tsai M Y, et al. Air pollution modeling over very complex terrain: An evaluation of WRF Chem over Switzerland for two 1-year periods[?]. Atmospheric Research, 2013, 132(5): 209-222.

[?] Li Da, Jiang Jiawen, Chen Boyang, et al. Study on the total emission control of atmospheric pollutants in Urban district[?]. Environmental Science, 1999, 20(5): 100-104.

[?] Xu Yanling, Xue Wenbo, Wang Jinnan, et al. Development and prospect of atmospheric environment capacity theory and accounting method[?]. Research of Environmental Sciences, 2018, 31(11): 1835-1840.

[?] Xu Dahai, Zhu Rong. A study on the distribution of ventilation and rainout capacity in mainland China[?]. China Environmental Science, 1989, 9(5): 367-374.

[?] Xu Dahai, Zhu Rong, Pan Zaitao. The studies on standard of emission of SO2 and dispersion model in cities[?]. China Environmental Science, 1990, 10(4): 309-313.

[?] Xu Dahai, Wang Yu, Zhu Rong. The atmospheric environmental capacity coefficient cumulative frequency curve fitting and its application[?]. China Environmental Science, 2016, 36(10): 2913-2922.

[?] An Xingqin, Chen Yuchun, Lü Shihua. Study on SO2 atmospheric environmental capacity in Lanzhou winter[?]. Plateau Meteorology, 2004, 23(1): 110-115.

[?] Guo Liping, Qiao Lin, Shi Minghua, et al. Analysis about meteorological conditions of continuous heavy pollution episodes in Langfang of Hebei Province[?]. Journal of Arid Meteorology, 2015, 33(3): 497-504.

[?] Sun Wenjie. Research on atmospheric environment capacity of Lanzhou new area based on WRF/CALMET simulation[?]. Environmental Impact Assessment, 2021, 43(3): 61-66.

[?] Liu Zilong, Dai Bin, Cui Zhuoyan, et al. Concentration characteristics and potential source of atmospheric pollutants: A case study in Urumqi[?]. Arid Zone Research, 2021, 38(2): 562-569.

[?] Zhu Rong, Zhang Cunjie, Mei Mei. The climate characteristics of atmospheric self-cleaning ability index and its application in China[?]. China Environmental Science, 2018, 38(10): 3601-3610.

[?] Yang Yunyun, Li Yueqing, Zhou Hui, et al. Spatial temporal variation characteristics of air pollution index and effects of meteorological condition in Changsha[?]. Meteorological and Environmental Sciences, 2017, 40(1): 108-113.

[?] Lu Chenli, Li Haijun, Zhang Xuehui, et al. Comparative analysis on two severe hazes happened in December 2013 in the north part of northern Zhejiang[?]. Meteorological and Environmental Sciences, 2018, 41(1): 47-55.

[?] Liu Qiang. Summary of methods about determination of atmospheric stability in environmental impact assessment[?]. Journal of Arid Meteorology, 2011, 29(3): 355-361.

[?] Li Bo, Wang Ying, Zhang Jiaxuan, et al. Ventilation coefficient in river valley terrain[?]. Research of Environmental Sciences, 2018, 31(8): 1382-1388.

[?] Wang Ying, Liang Yiling, Wang Lixia. Research on the impact of meteorological field on the spatial distribution of the pollutant concentration[?]. Desert and Oasis Meteorology, 2015, 9(2): 69-74.

[?] Wu Xupeng, Liu Duanyang, Xie Zhenzhen, et al. Change characteristics and relationship with meteorological conditions of atmospheric pollution in Huai an[?]. Meteorological and Environmental Sciences, 2018, 41(1): 31-38.

[?] Chen Boli, Lei Zhengcui, Dong Qin, et al. Analysis of the meteorological conditions in serious air pollution days in Changzhou from 2012 to 2014[?]. Meteorological and Environmental Sciences, 2017, 40(1): 87-94.

[?] Zhao Deshan. Handbook on the Total Quantity Control of Urban Air Pollution[?]. Beijing: China Environmental Science Press, 1991.

[?] Fan Jie. Guidelines for Assessment Methods of Resources and Environment Carrying Capacity and Land and Space Development Suitability[?]. Beijing: Science Press, 2022.

[?] Liu Longhua, Tang Xiaohua, Chen Jiabing. A research on bearing capacity of atmospheric environmental in Fujian Province[?]. Journal of Subtropical

Resource and Environmental, 2013, 8(4): 31-39.