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STUDY OF AIR CARRYING CAPACITY OF AYODHYA CITY, UTTAR PRADESH, INDIA

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Abstract: In the present study, atmospheric carrying capacity was estimated based on ventilation coefficient. Ventilation coefficient is directly proportional to the atmospheric carrying capacity that was computed by using micrometeorological parameters of two seasons *namely* winter and summer. The diurnal variation in ventilation coefficient was recorded. The highest value of air carrying capacity was observed during the afternoon hours and it decreases in morning and evening hours in both the seasons. It was noticed that the winter season has low air carrying capacity throughout the day as compared to summer. The value of ventilation coefficient was observed to be less than 2000 m^2/s during morning and evening hours in winter. Whereas, higher ventilation coefficient value lower than 8000 m^2/s was recorded during the summer season.

Keywords: Air carrying capacity, Mixing height, Pollution potential, Ventilation coefficient.

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INTRODUCTION

Pollution in any form is dangerous to all living creatures including humans both in rural and urban establishment (Balwan and Saba, 2021). Anthropogenic activities mostly contribute in the generation of all types of pollutions that in turn cause biodiversity threats (Verma, 2018; Vinod *et al.*, 2021; Prakash and Verma, 2022; Patel *et al.*, 2022). Among them, air pollution is major one. The urban air pollution around the world has become one of the major issues in recent decades because of its detrimental effect on human health and environment (Ghorani *et al.*, 2016). Industrial revolution had resulted in release of huge concentration of gaseous and particulate matter into the environment (Manisalidis *et al.*, 2020).

Currently, in addition to industrial emission, vehicular emission has become one of the major factors for enhanced air pollution in cities (Pant and Harrison, 2013; Gulia *et al.*, 2015). Air pollution causes nearly 4.2 million deaths every year and hence it is considered as a multifaceted international public health issue (WHO, 2021). United States Environmental Protection Agency (USEPA) had established the National Ambient Air Quality Standards (NAAQS) for six prevalent pollutants, known as 'criteria pollutants' including ground-level ozone (O_3), lead, carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_3), and particulate matter (PM10) (Huang and Brook, 2011).

Air pollution causes various health effects in sensitive groups of people including children and older ones even on less air pollution days. Short-term exposure of air pollutants causes diseases like COPD (Chronic Obstructive Pulmonary Disease), cough, shortness of breath, wheezing, asthma, respiratory diseases etc. However, long-term exposure to air pollutants is associated with chronic asthma, pulmonary insufficiency, skin disease, cardiovascular diseases and mortality (Manisalidis *et al.,* 2020). Meteorological parameters are most important factors influencing the fate of air pollutants. The diffusion of gases in the environment is influenced by meteorological factors such as wind velocity, atmospheric wind direction, temperature, mixing height, solar radiation, and relative humidity.

The meteorology plays a significant role in the research of air pollution (Hou and Wu, 2016). In terms of diffusion, mixing, and dispersion of pollutants in the atmosphere, meteorological conditions are one of the most important aspects that limit pollution. As a result, carrying capacity is used to assess the maximum pollutant potential that can be emitted into the environment (Prakash *et al.*, 2017).

The maximum pollutant load carrying capacity of the atmosphere is determined by different meteorological conditions (Panda and Nagendra, 2017). Ventilation coefficient, proportional to the carrying capacity of the atmosphere, is calculated in order to find out the pollution load. It is dependent on meteorological parameters. The present study was conducted from the December 2019 to May 2020 to determine the ventilation coefficient and variation in the carrying capacity of atmosphere in the holy city of Ayodhya, India.

MATERIALS AND METHODS

1. Study area

Ayodhya is a holy city situated at the bank of river Saryu about 130 km east of state capital of Uttar Pradesh *i.e.* Lucknow, India. Ayodhya city is situated at 82°12°16° E longitude and 26°47^{O}56^{O} N latitude and has an elevation of 102 meters above mean sea level. Ayodhya has humid subtropical climate, summers are long, dry and hot, extending from late March to July, with a temperature range of 35 to 45^{O}C.Whereas, winter temperature ranges from 6 to 25 °C starting from November to February.

Ayodhya receives nearly 1100 mm of annual rainfall, out of which more than 85% during the month of June to September (southwest monsoon). Ayodhya has gained enormous attention because of its religious importance. Large number of developmental activities including road and building construction, uncontrolled burning activities, and increase in the motor vehicle traffic are becoming the main factor for polluting the quality of air. Monitoring station at Naka Bypass with latitude 26.7963° N, longitude 82.2007° E, situated near the Lucknow Ayodhya highway was established for collecting data of air pollutants like SO_2, NO_2 and PM10 is established and working. The meteorological data (temperature, wind speed, precipitation, and relative humidity) was provided by the Department of Agricultural Meteorology of Acharya Narendra Dev University of Agriculture and Technology(formerly Narendra Dev University of Agriculture and Technology), is a university located in Kumarganj, Uttar Pradesh, India.

2. Mixing height data

For estimating the atmospheric carrying capacity, ventilation coefficient was calculated as it is directly proportional to it. Temperature, wind speed, humidity, precipitation, mean mixing height, and other meteorological factors influence the dispersion of air pollutants. In this study, hourly and daily data of mixing height was obtained by using AERMOD dispersion model. The ability of a region's environment to transport pollutants without causing negative impacts on the environment or users of its resources is called to as assimilative capacity or carrying capacity (Karuna *et al.*, 2017). The ventilation coefficient, which can be estimated by using weather parameters such as wind speed and maximum mixing height, is directly proportional to the carrying capacity of the atmosphere. The ventilation coefficient is estimated by the product of mixing height and the average wind speed in winter and summer seasons. The ventilation coefficient is estimated by the product of mixing height and the average wind speed in winter and summer seasons. The ventilation coefficient is estimated by the product of mixing height and the average wind speed in winter and summer seasons. The ventilation coefficient is calculated using equation below:

Ventilation coefficient (m^2/s=wind speed (m/s) x Mixing height (m)

The atmosphere will be considered as low contamination potential when ventilation coefficient> 12000 m^2/s, medium contamination potential with ventilation coefficient~ 6000-12000 m^2/s. According to the United States Meteorological Center and Atmospheric Environmental Services, Canada, high contamination potential or classified as 'poor' will be considered, when ventilation coefficient is <6000 m^2/s (during afternoon), mean wind speed is <4 m/s, and mixing height is <500 m (during morning)(Prakash *et al.,* 2017; Goyal *et al.,* 2006).

RESULTS AND DISCUSSION

Dispersion of air pollutants depends upon meteorological factors; hence daily average data of ventilation coefficient was determined to plot the seasonal variation between mixing height and ventilation coefficient.

1. Seasonal variation of mean mixing height

The variation in mixing height was mainly because of variation in temperature as well as wind speed. The diurnal variation of mixing height for summer and winter season is shown in Figure 1. The value of mixing height was found to be less than 400 m in morning hours (07:00 h to 09:00 h) and evening hours (17:00 to 19:00 h) during winter season. Whereas, the value of mixing height was found to be less than 800 m in morning hours (07:00 h to 09:00 h) and less than 1600 m in evening hours (17:00 to 19:00 h) during summer season. Average maximum value of mixing height was observed between 977.73 and 2704.34 m during11:00 to 14:00 h in winter and summer seasons, respectively. The mixing height value was low during morning and evening hours, might be due to occurrence of ground-based inversion or low solar isolation and high moisture content that hampers the dispersion.

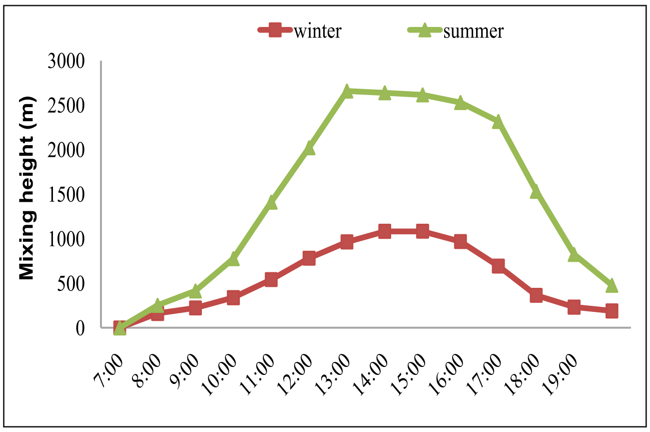

Fig. 1. Diurnal variation of mixing height during winter and summer seasons.

2. Carrying capacity based on ventilation coefficient

The atmospheric carrying capacity of Ayodhya city has been analyzed. The ventilation coefficient was determined by using mixing height and wind speed for two seasons *namely* winter and summer. The value of ventilation coefficient and mixing height for winter and summer at Ayodhya are shown in table1. Figure 2 represents the diurnal variation of carrying capacity during winter season, whereas figure 3 represents the diurnal variation of carrying capacity during summer season.

In this study, investigation revealed that in morning and evening time mixing height values in both seasons are low as compared to daytime. It might be due to low solar heating and high moisture content in atmosphere. It is evident from the table 1, that the value of ventilation coefficient was lower than 2000 and 8000m^2/s during morning hours (07:00 to 11:00 hour) in winter and summer seasons respectively. On the other hand, the value of ventilation coefficient was observed higher than 4000 and 8000 m^2/s during 11:00 to 16:00 hours in winter and summer seasons respectively.

In the winter season the mixing height is low as compared to summer season. This is mainly due to slightly higher wind speed during summer season. Due to low wind speed and mixing height, the value of ventilation coefficient was lower in winter as compared to summer season. Hence, high level of pollutants was observed during winter season in the atmosphere. From fig. 1 and 2, it is clear that low ventilation coefficient during early morning and evening that indicates high pollution potential and low carrying capacity. However, in the daytime, higher ventilation coefficient was observed indicating low pollution potential and good atmospheric carrying capacity.

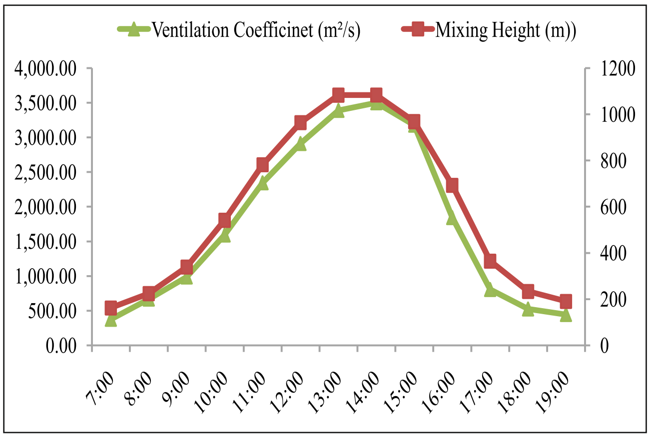

Fig. 2: Diurnal variation of Ventilation Coefficient and mixing height during winter.

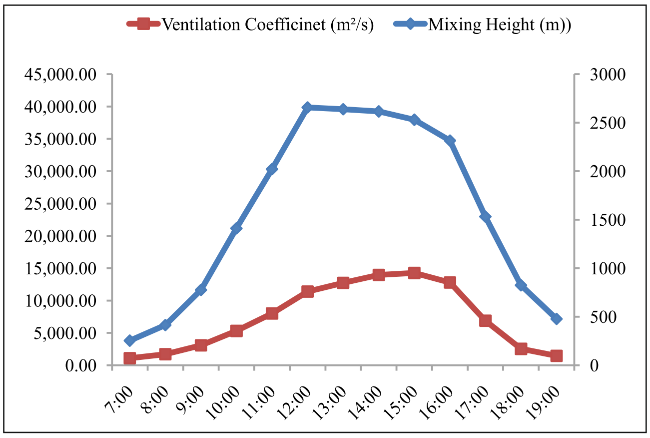

Fig. 3: Diurnal variation of Ventilation Coefficient and mixing height during summer season.

Table 1: Mixing height and Ventilation coefficient value at respective hours of winter and summer seasons.

Hour	Winter		Winter	
	Mixing height (m)	Ventilation coefficient (m²/s)	Mixing height (m)	Ventilation coefficient (m²/s)
7:00	161.92	375.65	252.95	1,097.80
8:00	223.85	667.07	414.57	1,703.88
9:00	338.76	985.79	776.98	3,084.61
10:00	541.21	1,591.16	1411.44	5,307.01
11:00	781.41	2,344.23	2021.89	8,006.68
12:00	963.85	2,910.83	2658.2	11,403.68
13:00	1082.59	3,388.51	2638.97	12,746.23
14:00	1083.07	3,498.32	2615.7	13,967.84
15:00	968.16	3,175.56	2529.89	14,268.58
16:00	692.64	1,842.42	2316.82	12,788.85
17:00	364.44	805.41	1532.71	6,881.87
18:00	233.08	524.43	824.29	2,538.81
19:00	190.15	444.95	477.92	1,452.88

CONCLUSIONS

On the basis of above exploration, it can be concluded that the ventilation coefficient in Ayodhya city was less than 2000 m^2/s in the morning and evening hours during the winter months whereas mixing height did not exceed 400 m during morning and evening hours. it clearly indicates that this holy city has high pollution potential showing low atmospheric carrying capacity. The air carrying capacity was found to be better in summer season as compared to winter season.

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