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Assimilative capacity of the atmosphere at Gorakhpur with respect to air pollution

P. K. NANDANKAR

Regional Meteorological Centre, Colaba, Mumbai - 400 005, India

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सार - इस शोध-पत्र में पूर्वी उत्तर-प्रदेश के गोरखपुर क्षेत्र में मौसमी तथा दैनिक प्रदूषण की आशंकाओं का अध्ययन किया गया है। प्रदूषण की आशंकाओं का पता लगाने के लिए चार ऋतुओं नामतः शीत ऋतु (दिसंबर से फरवरी तक), ग्रीष्म ऋतु (मार्च से मई तक), मानसून ऋतु (जून से सितंबर तक), और मानसून समाप्ति की ऋतु (अक्तूबर से नवंबर तक) के गोरखपुर क्षेत्र के पाँच वर्षों की अवधि (1982 से 1986) तक के मौसम विज्ञान के आंकड़ों का विश्लेषण किया गया है। इसके लिए ऋतु-वार वायु आरेख, स्थिरता और स्थिरता आरेख तैयार किए गए हैं तथा वायु की मिलीजुली तीव्रता और संवातन गुणांक के ऋतु-वार दैनिक परिवर्तन संबंधी कार्य भी किए गए। इससे यह पता चला है कि गोरखपुर क्षेत्र में ग्रीष्म त्रतु के दौरान विसरण की क्षमता बेहतर पाई गई है। जबकि मानसून समाप्ति पर तथा तत्पश्चात् शीत ऋतु में यह क्षमता कमजोर पाई गई है। उर्ध्वाधर मिश्रण के लिए दिन का समय बेहतर पाया गया है। केवल मानूसन ऋतु को छोड़कर जब वायु उत्तर पूर्वी दिशा से पूर्व की ओर चलती है अन्य सभी ऋतुओं में वायु वेग दक्षिण पश्चिमी दिशा से पश्चिम की दिशा में अधिक प्रबल रहा है। इस अध्ययन के आधार पर यह सुझाव दिया गया है कि औद्योगिकीकरण के लिए यह उपयुक्त स्थान है।

ABSTRACT . The present study aims at seasonal and diurnal pollution potential at Gorakhpur in east Uttar Pradesh. To assess the pollution potential, meteorological data for five year period (1982-86) of Gorakhpur have been analyzed for four seasons *viz*; winter (December-February), summer (March-May), monsoon (June-September) and post monsoon (October-November). Season wise wind roses, stability, stability wind roses have been prepared and season wise diurnal variation of mixing height and ventilation coefficient have also been worked out. It is found that Gorakhpur has a better diffusion capacity in summer and poor in post monsoon followed by winter. Afternoon hours are better for vertical mixing. The winds are predominantly from southwest to west in all seasons except in monsoon when it blows from northeast to east. Based on this study, an appropriate location for industrialization has been suggested.

Key words – Windrose, Mixing heights, Ventilation coefficient, Stability, Pollution potential.

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1. Introduction

The assimilative capacity of the atmosphere over a place is determined by dilution and dispersion of the pollutants. Air pollution climatology explains the ability of the atmosphere to dilute, disperse or stagnate the pollutants over a place at any time. Wark and Warner (1976) have stated that the pollution level at any place and time represents the balance between rate of emission from their sources and the rate at which they are removed from the atmosphere. Gorakhpur (Lat 26° 45′ /Long 83° 22′) is a major city in east Uttar Pradesh facing enormous atmospheric pollution problem due to rapid industrialization and increase in vehicular activity. Upper air meteorological data is available only from this place in the east Uttar Pradesh. Thus it is aimed to assess the assimilative capacity of the atmosphere over Gorakhpur with respect to pollution, which may be useful for identification of areas for new industrial set up, urban planning and air quality management.

2. Data and method of analysis

To identify the role of climatic factors in diffusion of air pollutants released in the atmosphere over Gorakhpur, variation of wind, stability, mixing height and ventilation coefficient has been worked out for this purpose. The meteorological data of Gorakhpur for five-year period (1982-86) have been used in this study. Daily upper air data recorded at 0530 hrs IST have been used for computation of mixing heights and ventilation coefficients. Daily surface data on wind, cloud, and temperature recorded every three hours have also been utilised for preparation of wind roses, stabilities and mixing heights and ventilation coefficients. Three hourly surface wind data has been sorted out season wise for four seasons *viz*; winter (December to February), summer (March to May), monsoon (June to September), and post monsoon seasons (October to November).

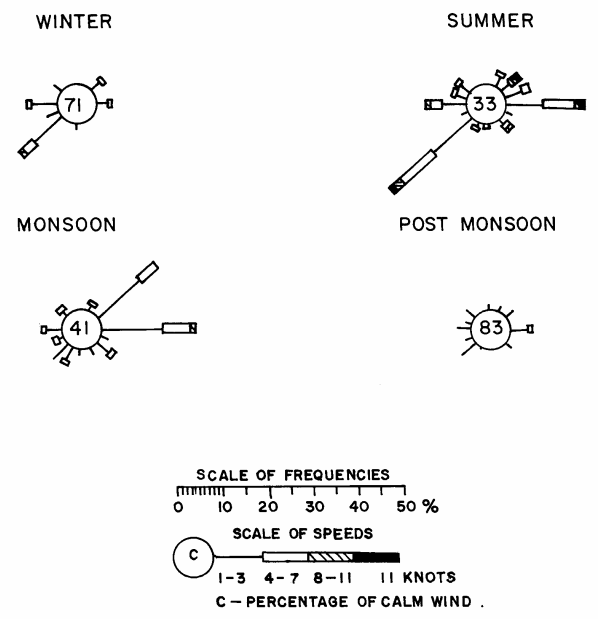

Fig. 1. Seasonal wind roses

On preliminary analysis, it is found that no significant diurnal variation has been observed in wind. Therefore a sixteen-point wind rose for each season has been prepared. Seasonwise surface meteorological data has been sorted out and Pasquill Stability Classes were determined using Turner's (1964) method for every synoptic hour. Season wise upper air data at 0530 hrs IST have been sorted out separately and plotted on T-Φ gram. Daily upper air data at 0530 hrs IST has been used for computation of mixing height and ventilation coefficient. Mixing height is determined by extending the dry adiabat from surface temperature to its intersection with the morning temperature sounding (Holzworth, 1967). The height of the point of intersection from ground is termed as mixing height. The mixing height at every synoptic hour has been computed by extending the dry adiabat from the surface temperature corresponding to the given synoptic hour to intersect morning sounding. The daily mixing height at every synoptic hour has been calculated and averaged out at every synoptic hour season wise. The ventilation coefficient at any time can be obtained by multiplying the mixing height at that time and the mean wind speed through the mixing layer. From the ventilation coefficient computed daily for every synoptic hour, seasonal average ventilation coefficients have been worked out.

3. Result and discussion

3.1. *Wind*

The seasonal wind roses have been prepared and presented in Fig. l. Generally, the frequencies of occurrence of calm periods are higher in post monsoon (83%) followed by winter (71%) and lesser in summer (33%) followed by monsoon season (41%). The wind speed rarely exceeds 11 kt in summer and 8 kt in other seasons except in post monsoon. Very light winds prevailed in the post monsoon. The predominant winds are from southwest in all seasons except in monsoon when wind mostly blows from northeast to east direction. Generally, winds blowing from southwest to west direction are stronger compared to the winds blowing from any other direction. Winds not only determine the travel time of pollutants from the source to a given receptor but also the ground level concentration. Calm/weak winds deteriorate air quality. Thus better dispersal of pollutants is expected in summer and poor in winter.

3.2. *Stability*

The percentage frequency of occurrence of the seven stability classes during every synoptic hour in the four seasons have been presented in Table 1. It is noticed that unstable conditions during nighttime and stable condition during daytime have not occurred in all the seasons. In winter, "A" (extremely unstable) condition is more frequent at 1130 hrs IST; "B" (moderately unstable) condition at 1430 hrs IST; "C" (slightly unstable) conditions at 1730 hrs IST and "D" (neutral) condition at 0830 hrs IST. Similarly, "G" (extremely stable) condition is more frequent at 2330 hrs IST; "E" (slightly stable) at 0230 hrs IST and "F" (moderately stable) at 2030 hrs IST. In summer, "A" stability condition is more frequent at 1130 hrs IST, "B" stability condition at 0830 hrs IST and "C" stability condition at 1730 hrs IST. However "D" stability conditions is significant at all synoptic hours and more frequent at 1730 hrs IST. "G" stability is significant during nighttime and more frequent at 2030 hrs IST, whereas "E" and "F" condition are insignificant during nighttime. In monsoon, "D" stability is significant at all synoptic hours and more frequent at 1130 hrs IST. "B" and "C" conditions are predominant during daytime. However, "B" stability is more frequent at 0830 hrs IST. In this season, "G" stability is less predominant as compared to "F" condition during nighttime. "E" stability is also insignificant during nighttime. In the post monsoon, "A" stability is more frequent at 1130 hrs IST; "B" stability at 1430 hrs IST; "C" and "D" stability at 0830 hrs IST. Similarly "G" is predominant and more frequent at 0230 hrs IST. "E" and "F" stability are less frequent compared to "G".

Extremely unstable conditions have occurred at 1130 and 1430 hrs IST with high frequencies in all seasons except monsoon. Extremely stable conditions have occurred during nighttime especially after 2030 hrs IST.

TABLE 1

Percentage frequency of stability classes at Gorakhpur

Time (IST)	Percentage frequency stability class						
	A	B	C	D	E	F	G
				Winter			
0830	8.0	10.7	18.2	63.1	0.0	0.0	0.0
1130	66.2	9.8	6.9	17.1	0.0	0.0	0.0
1430	58.7	17.2	7.3	16.8	0.0	0.0	0.0
1730	0.0	0.0	93.0	7.0	0.0	0.0	0.0
2030	0.0	0.0	0.0	0.0	1.8	21.0	77.2
2330	0.0	0.0	0.0	0.0	2.6	14.8	82.6
0230	0.0	0.0	0.0	3.0	7.1	19.4	70.5
0530	0.0	0.0	0.0	4.1	4.6	16.3	75.0
				Summer			
0830	14.0	53.9	23.2	8.9	0.0	0.0	0.0
1130	41.3	38.0	15.9	4.8	0.0	0.0	0.0
1430	4.0	36.1	30.9	29.0	0.0	0.0	0.0
1730	0.0	0.0	31.0	69.0	0.0	0.0	0.0
2030	0.0	0.0	0.0	6.1	10.2	19.7	64.0
2330	0.0	0.0	0.0	11.3	11.8	25.8	51.1
0230	0.0	0.0	0.0	7.1	15.5	27.4	50.0
0530	0.0	0.0	0.0	5.3	11.8	23.9	59.0
				Monsoon			
0830	2.0	38.4	13.6	46.0	0.0	0.0	0.0
1130	3.1	12.8	5.8	78.3	0.0	0.0	0.0
1430	0.0	2.1	27.5	70.4	0.0	0.0	0.0
1730	0.0	0.0	27.1	73.0	0.0	0.0	0.0
2030	0.0	0.0	0.0	35.6	15.5	42.8	6.1
2330	0.0	0.0	0.0	35.0	13.0	41.0	11.0
0230	0.0	0.0	0.0	33.0	15.6	41.9	9.5
0530	0.0	0.0	0.0	33.3	12.4	45.8	8.5
				Post-Monsoon			
0830	6.1	15.9	23.9	54.1	0.0	0.0	0.0
1130	62.8	14.5	14.5	8.2	0.0	0.0	0.0
1430	21.2	41.7	12.3	24.8	0.0	0.0	0.0
1730	0.0	0.0	0.0	8.5	3.1	22.0	66.4
2030	0.0	0.0	0.0	9.0	3.7	14.3	73.0
2330	0.0	0.0	0.0	8.6	2.2	17.6	71.6
0230	0.0	0.0	0.0	9.1	0.0	16.7	74.2
0530	0.0	0.0	0.0	6.7	1.1	21.5	64.7

A – Extremely Unstable; B – Moderately Unstable; C – Slightly Unstable; D – Neutral;
E – Slightly Stable; F – Moderately Stable; G – Extremely Stable

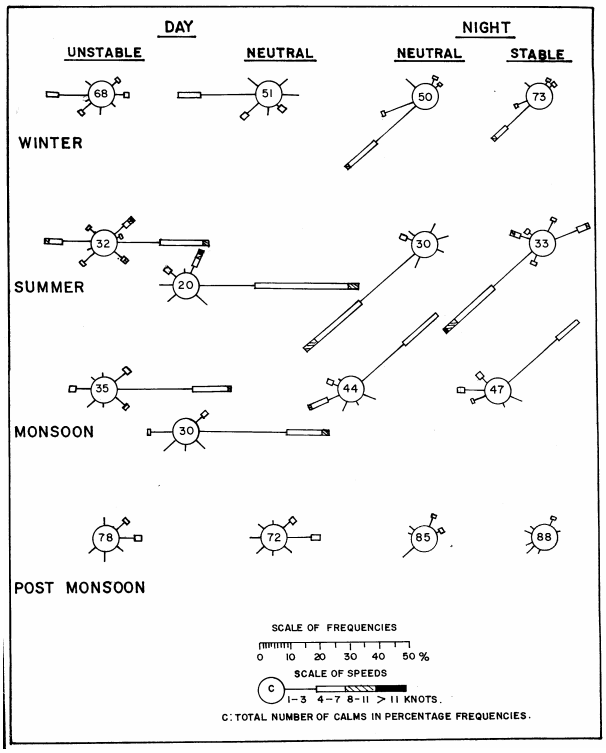

Fig. 2. Stability windroses

Other stability conditions are less frequent in all the seasons. The neutral conditions are more frequent in monsoon compared to other seasons. Therefore, efficient dispersion of pollutants during daytime in all the months can be expected. Of the four seasons, better diffusion of pollutants can be expected during summer and monsoon seasons.

3.3. *Stability wind roses*

From the winds during the three stability classes (A-C, D, E-G) both in day and night time stability wind roses have been prepared and presented in Fig 2.

In winter, during daytime 61% and 51% of calm periods during unstable and neutral conditions have been observed. The winds predominantly blow from southwest to west direction. During nighttime, 50% and 73% of calm periods have been observed respectively during neutral and stable conditions. The predominant winds are from southwest in neutral and stable conditions.

In summer, during daytime 32% and 20% calm periods have been observed under unstable and neutral conditions respectively. The dominant winds are from east direction under both conditions. During nighttime, 30% and 33% of calm periods have been observed under neutral and stable conditions respectively. The dominant winds are southwesterly under both the conditions. Weak winds are observed under stable condition during nighttime but stronger winds under unstable and neutral conditions during daytime.

In monsoon during daytime, 14% and 5% calm periods have been observed under unstable and neutral conditions respectively. The dominant winds are easterlies under both conditions. During nighttime, 44% and 47% of the calm periods have been observed under neutral and stable conditions respectively. The predominant winds are northeasterlies under both conditions.

In post monsoon, during daytime, 78% and 72% calm periods have been observed under unstable and neutral conditions respectively. The predominant winds are northeast to east under both the conditions. During nighttime, 85% and 88% of calm periods have been observed under neutral and stable conditions respectively. The predominant winds are easterlies under neutral conditions.

Maximum calm periods have been observed under stable condition during nighttime and minimum under neutral condition during daytime. It is therefore concluded that poor diffusion conditions exist during nighttime in all seasons. It can be also concluded that better diffusion conditions exist in summer and monsoon seasons.

3.4. *Mixing height and ventilation coefficient*

Diurnal variation of mean mixing height and ventilation coefficient are presented in Figs. 3&4 respectively. The afternoon mixing height has been observed higher (1570 m) in summer and lower (1005 m) in monsoon season. Afternoon mixing heights in the winter are comparatively lower than the monsoon mixing heights. The highest mixing height is observed between 1430 to 1730 hrs IST and lowest during late night. The range of diurnal variation of mixing height in summer is very large and small in winter. Winter and post monsoon seasons do not show significant variation in mixing height.

The afternoon ventilation coefficient has been observed more (13900 m^2/sec) in summer and less (4900 m^2/sec) in post monsoon. The highest ventilation coefficient was observed between 1430 to 1730 hrs IST and lowest during late night. The range of diurnal variation of ventilation coefficient in summer is also large compared to other seasons. No significant diurnal variation in ventilation coefficient has been observed in

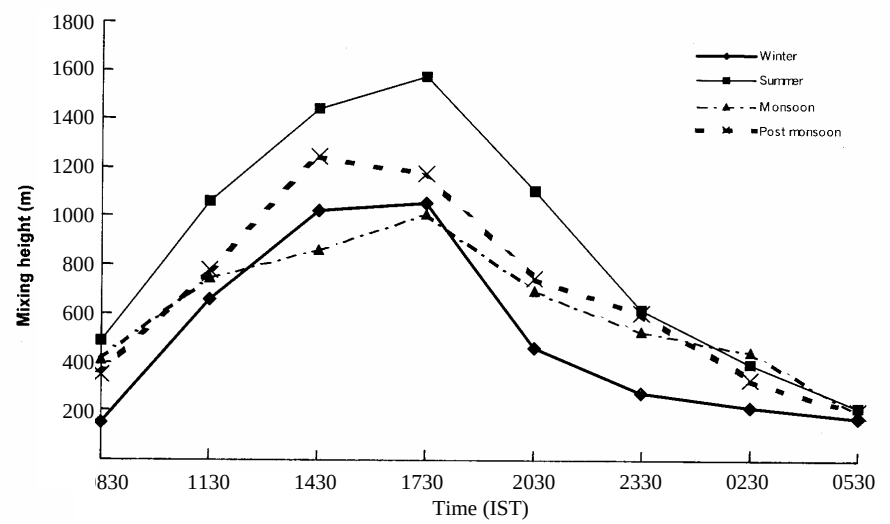

Fig. 3. Mean mixing height

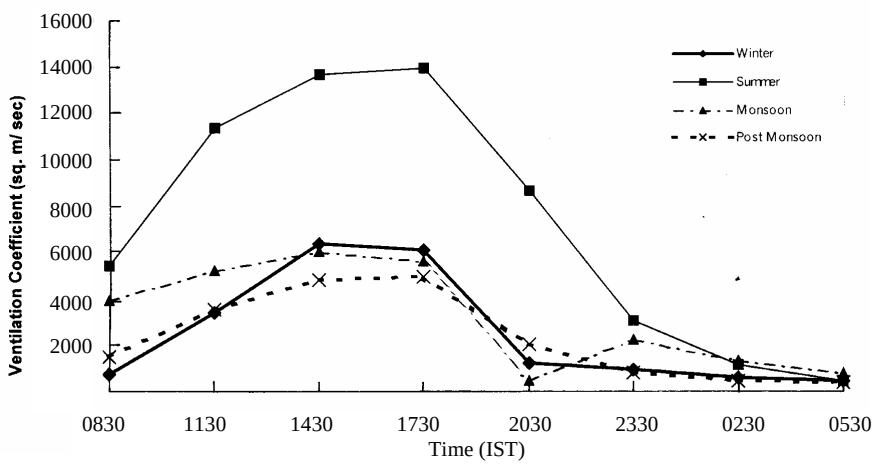

Fig. 4. Mean ventilation coefficient

monsoon, winter and post monsoon season. The afternoon ventilation coefficient in summer is almost double than that observed in any other season. By applying Gross (1970) criteria of forecasting high pollution potential in this study; it is found that Gorakhpur has high pollution potential in late night to early morning hours in all seasons, which gradually decreases during noon hours and eventually disappears in the afternoon/early evening. Therefore, a good vertical mixing of contaminants is expected in the afternoon/evening hour and poor in late night in all seasons. Good vertical mixing of contaminants and better ventilation is also expected in summer.

4. Conclusion

More calm winds have been observed in post monsoon followed by winter and less in summer season. The winds are more frequent from southwest to west in all seasons except in monsoon where it blows from northeast to east. Thus, it is inferred that better dispersal capacity exists in summer and poor in winter. No major polluting industries should be set up in the southwest to west sector of the city. Highly unstable conditions are more frequent at midday and stable conditions are in winter and post monsoon season. Stability wind roses also show maximum calm winds under stable condition during nighttime and minimum under neutral condition during daytime. Thus it is concluded that poor dispersal conditions exist during nighttime in all seasons. It is also concluded that better diffusion conditions exist in summer and monsoon seasons.

Highest afternoon mixing height and ventilation coefficient occurred in summer. Gorakhpur has got high pollution potential in the night to early morning hours in all

seasons, which gradually decreases, in the noon hours and eventually disappears in the afternoon/early evening hours. Therefore, it is concluded that good vertical mixing and better dispersal of contaminants is expected in the afternoon/evening hours and poor in late night in all seasons. It is also concluded that summer season has got better dilution capacity.

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