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# On pollution potential at Visakhapatnam

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ABSTRACT. Climatology of ground based and elevated inversions, multiple inversions, their thickness, lapse rate and mean wind speed through their heights for visakhapatnam based on 00 and 12GMT ascents during December-March for the year 1974-78 suggests that pollution potential at Visakhapatnam is high during December-February. Mean monthly morning and afternoon mixing depths and ventilation coefficients are found to be low from December to February hence pollutant concentration is likely to increase if released into the atmosphere. The percentage frequency of days when the morning mixing depth and transport wind speed and the afternoon ventilation co-efficient and transport wind speed which satisfy the stipulated criteria for high pollution potential point out that control measures to alleviate the pollution problems are to be taken between December and February.

## 1. Introduction

Low based inversions, light winds in the mixing layer with no significant precipitation are favourable conditions for accumulation of pollutants. Owing to increasing industrialisation and urbanization air quality at Visakhapatnam is getting deteriorated very fast. Further radiation and advection inversions with clear skies and little precipitation in most of the days during December-March play a key role in increasing the pollution potential. The low level stable layers and weak winds through the layer reduce the vertical mixing and create stagnation conditions. In this paper a climatological study of the inversions, stable layers and pollution potential at a coastal station, Visakhapatnam, was made. A comparison with an inland station like Delhi has also been made to identify the peculiarities.

## 2. Methodology

Inversions, their thickness and lapse rates and mean wind speed are obtained from Radiosonde data of 00 and 12 GMT of Visakhapatnam. Ventilation coefficient, a product of the mixing height and the transport wind, is a measure of the volume rate of horizontal transport of air within the mixing layer, per unit distance normal to the wind. The criterial for forecasting high pollution potential are that the morning mixing depths should be $\leqslant$ 500 m and transport wind speed $\leqslant$ 4m/sec and afternoon's ventilation coefficient $\leqslant$6000 $m^2$/sec and transport wind speed $\leqslant$ 4m/sec (Gross 1970). This criterial is widely used by U.S. National Meteorological Centre (Gross 1970) and Atmospheric Environment Service Canada (Boucaud *et al.* 1972 unpublished). In the absence of any criteria for high pollution potential in India an attempt has been made in this paper to delineate periods of high pollution potential at Visakhapatnam utilising the above criteria. Data used in the study refers to the period 1974-78.

## 3. Results and discussion

### 3.1. *Percentage frequency of stable layers under different wind speeds*

Stable layers include ground based inversions, lifted inversions and isothermal layers. Percentage frequency of ground based inversions at 00 GMT (Table 1a) is high in the height range 201-300m and low in the height range 0-100m and above 1000 m. Percentage frequency of the above is generally maximum when the wind speed is $\leqslant$ 4m/sec upto 400 m but the frequencies are high with wind speeds $>$ 4m/sec later. This results in poor horizontal ventilation as well as vertical mixing. High percentage frequency of inversion heights in 201-300 m range could lead to fumigation conditions if the plumes are under 300 m in the morning. On the other hand if the pollutants are released above 400 m, it is possible that they may be dispersed quickly. The percentage frequency of elevated inversions is high in the height range $>$ 1000 m and is 35.5 per cent in the height range 501-1000 m. Percentage frequency of elevated inversions and isothermal layers are also high when the wind speed is greater than 4 m/sec.

Percentage frequency of ground based inversions at 12 GMT (Table 1b) is maximum in

TABLE 1

**Percentage frequency of ground based and elevated inversions and isothermal layers (1974-1978) at Visakhapatnam**

| Percentage frequency of | Range of mean wind (m/sec) through inversion and isothermal layers (m): 0-100 | | | 101-200 | | | 201-300 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0-2 | 2-4 | >4 | 0-2 | 2-4 | >4 | 0-2 | 2-4 | >4 |
| **(a) 00 GMT** | | | | | | | | | |
| Ground inversion | 00 | 00 | 00 | 4.6 | 2.6 | 3.4 | 9.9 | 14.0 | 12.0 |
| Ground inversion under wind speed interval 00 to > 4 (m/sec) | | 00 | | | 10.6 | | | 35.9 | |
| Elevated inversion | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 0.1 | 0.2 |
| Elevated inversion under wind speed interval 00 to >4 (m/sec) | | 00 | | | 00 | | | 0.3 | |
| Isothermal layers | 00 | 00 | 00 | 00 | 00 | 00 | 1.7 | 00 | 5.1 |
| Isothermal layers under wind speed interval 00 to >4 (m/sec) | | 00 | | | 00 | | | 6.8 | |
| **(b) 12 GMT** | | | | | | | | | |
| Ground inversion | 00 | 2.3 | 4.7 | 2.3 | 00 | 00 | 00 | 9.3 | 16.3 |
| Ground inversion under wind speed interval 00 to >4 (m/sec) | | 7.0 | | | 2.3 | | | 25.6 | |
| Elevated inversion | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| Elevated inversion under wind speed interval 00 to > 4(m/sec) | | 00 | | | 00 | | | 00 | |
| Isothermal layers | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| Isothermal layers under wind speed interval 00 to >4 (m/sec) | | 00 | | | 00 | | | 00 | |

| Percentage frequency of | Range of mean wind (m/sec) through inversion and isothermal layers (m): 301-400 | | | 401-500 | | | 501-1000 | | | >1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-2 | 2-4 | >4 | 0-2 | 2-4 | >4 | 0-2 | 2-4 | >4 | 0-2 | 2-4 | >4 |
| **(a) 00 GMT** | | | | | | | | | | | | |
| Ground inversion | 6.6 | 8.7 | 7.9 | 2.6 | 2.6 | 7.9 | 3.3 | 4.0 | 9.9 | 00 | 00 | 00 |
| Ground inversion under wind speed interval 00 to >4 (m/sec) | 23.2 | | | | 13.1 | | 17.2 | | | | 00 | |
| Elevated inversion | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 1.6 | 4.0 | 9.3 | 22.3 | 6.7 | 24.0 | 31.0 |
| Elevated inversion under wind speed interval 00 to >4 (m/sec) | | 0.8 | | | 2.1 | | | 35.6 | | | 61.7 | |
| Isothermal layers | 0.8 | 0.8 | 00 | 0.8 | 00 | 3.3 | 1.7 | 6.7 | 25.0 | 5.8 | 13.3 | 35.0 |
| Isothermal layers under wind speed interval 00 to >4 (m/sec) | | 1.6 | | | 4.1 | | | 33.4 | | | 54.1 | |
| **(b) 12 GMT** | | | | | | | | | | | | |
| Ground inversion | 4.7 | 18.6 | 4.7 | 00 | 4.7 | 9.3 | 00 | 9.3 | 13.9 | 00 | 00 | 00 |
| Ground inversion under wind speed interval 00 to >4 (m/sec) | | 28.0 | | | 14.0 | | | 23.2 | | | 00 | |
| Elevated inversion | 00 | 0.2 | 0.2 | 0.7 | 2.1 | 3.1 | 1.5 | 11.9 | 34.0 | 1.2 | 16.7 | 28.4 |
| Elevated inversion under wind speed interval 00 to > 4(m/sec) | | 0.4 | | | 5.9 | | | 47.4 | | | 46.3 | |
| Isothermal layers | 00 | 00 | 0.6 | 00 | 1.2 | 0.6 | 2.4 | 15.1 | 12.5 | 3.0 | 17.6 | 37.0 |
| Isothermal layers under wind speed interval 00 to >4 (m/sec) | | 0.6 | | | 1.8 | | | 30.0 | | | 57.6 | |

Note—Percentage frequency of inversions in all the ranges was nil when the wind was calm

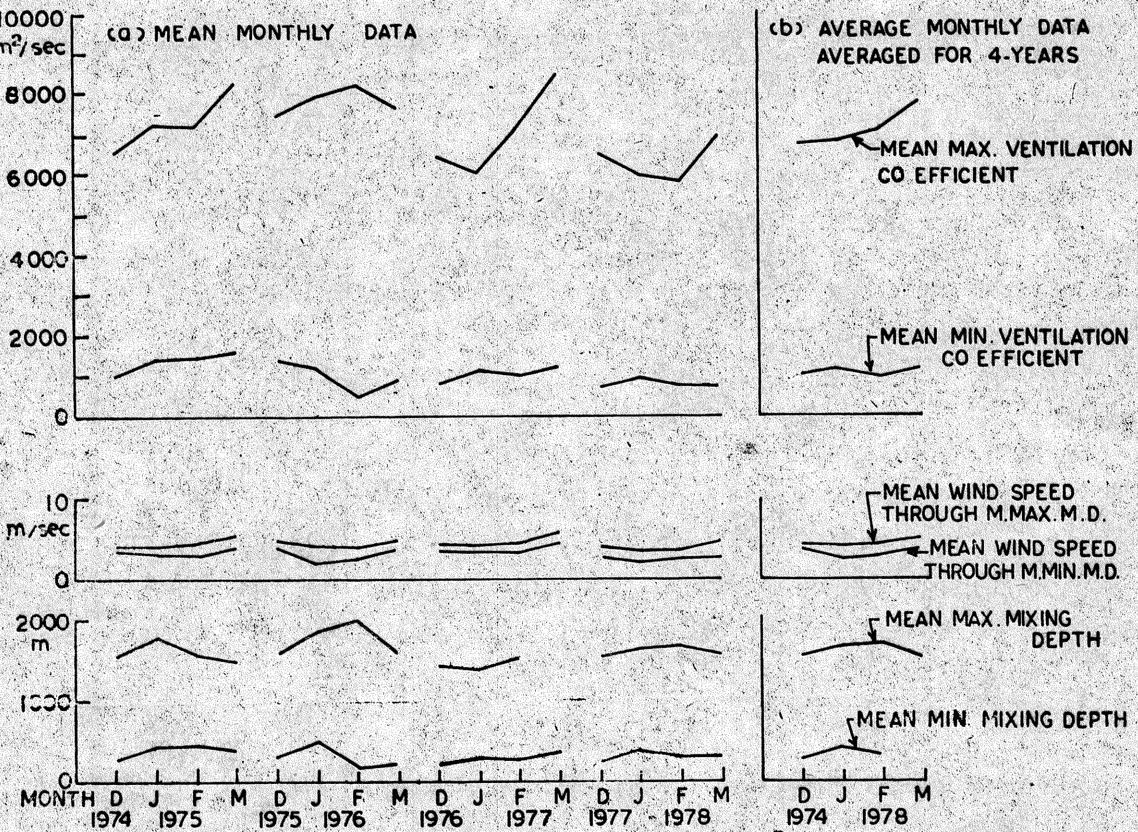


Fig. 1.

the height range 301-400 m when the wind speed is between 2 and 4 m/sec. Evening ground based inversions in the height range 0-100m are found to be greater than in the morning. Evening elevated inversions and isothermal layers show similar features of morning.

February is associated with maximum percentage frequency of morning inversions closely followed by March, December, January, while July is having minimum (Table 2 a). Inversions are high either in pre-monsoon or in winter seasons. Percentage frequency of isothermal layers is high in June and July and lowest in February. Stable layers are generally high from December and reach a peak value in March.

The percentage frequency of multiple inversions in a day has registered highest frequencies in December. In spite of comparatively low percentage frequency of ground based inversions high percentage frequency of stable layers and occurrence of multiple inversions in a day reduce the vertical mixing and consequently increase the pollution potential. Even ground based inversions and multiple inversions (Table 2b) are very small, but percentage frequency of evening elevated inversions are quite high.

3.2. *Lapse rate*

Percentage frequency of morning lapse rate (Table 3a) is high in May to November in the range 0-10 °C/km. December is a month of maximum percentage frequency in the high lapse rate. Because of this intense inversion, morning mixing depth is least in December (Padmanabhamurty and Mandal 1976). Season-wise distribution of lapse rate show that winter and pre-monson seasons have high percentage frequency in the range 20—50° C/km. The frequency of lapse rate at 12 GMT (Table 3b) show the same pattern as that of 00 GMT.

3.2.1. *Thickness of ground inversions*

Highest percentage frequency of thickness of morning ground based inversion (Table 4a) is generally in the height range 201-300m. High percentage frequency of inversions in the range under 50 m produces low afternoon mixing depths (Padmanabhamurty and Mandal 1976). Percentage frequency of thickness of evening ground inversions (Table 4b) is high below 400 m.

3.2.2. *Thickness of inversions and isothermal layers*

Percentage of inversions and isothermal layers (Table 5a) in the range 501-1000 m is highest in March and lowest in January. This suggests that January will have higher mixing depths than that of March. February which is associated with higher percentage frequency than January in the range 0-1000 m has registered lower mixing depth than January, (Fig. 1). Percentage fre-

TABLE 2

**Percentage frequency of monthly ground based and elevated inversions isothermal layers and multiple inversions (1974-78) at Visakhapatnam**

| Inversions | Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sept | Oct | Nov | Dec | Dec-Feb | Mar-May | Jun-Sept | Oct-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **(a) 00 GMT** | | | | | | | | |
| Ground | 13.0 | 18.8 | 18.6 | 12.5 | 11.4 | 10.3 | 00 | 7.7 | 9.0 | 6.3 | 6.8 | 14.7 | 15.5 | 14.5 | 7.0 | 6.5 |
| Elevated | 54.3 | 50.0 | 51.0 | 63.6 | 43.0 | 19.5 | 23.3 | 13.2 | 6.7 | 9.8 | 33.3 | 55.7 | 53.3 | 51.0 | 15.3 | 21.8 |
| Isothermal layers | 9.4 | 3.9 | 14.4 | 7.9 | 12.2 | 17.2 | 17.8 | 9.9 | 7.9 | 9.8 | 9.4 | 9.0 | 7.4 | 12.0 | 12.9 | 9.6 |
| Multiple (in a day) | 15.3 | 17.2 | 11.0 | 3.5 | 5.3 | 00 | 2.7 | 1.1 | 1.1 | 0.9 | 4.3 | 18.8 | 17.0 | 7.7 | 1.2 | 2.7 |
| | | | | | | | | **(b) 12 GMT** | | | | | | | | |
| Ground | 0.7 | 0.7 | 6.8 | 0.0 | 8.4 | 6.9 | 1.3 | 3.3 | 5.7 | 4.1 | 0.9 | 0.8 | 0.7 | 5.6 | 4.4 | 2.5 |
| Elevated | 38.4 | 29.1 | 47.9 | 73.9 | 42.1 | 20.7 | 21.6 | 9.9 | 7.9 | 7.3 | 26.0 | 36.3 | 34.6 | 52.6 | 14.7 | 16.4 |
| Isothermal layers | 13.8 | 18.6 | 9.8 | 3.6 | 13.1 | 9.2 | 12.1 | 16.4 | 12.5 | 12.2 | 7.0 | 14.8 | 15.8 | 9.3 | 12.6 | 9.6 |
| Multiple (in a day) | 5.0 | 1.5 | 30.1 | 1.2 | 2.8 | 0.0 | 0.0 | 0.0 | 1.1 | 0.0 | 0.9 | 5.8 | 4.1 | 2.5 | 0.3 | 0.4 |

TABLE 3

**Percentage frequency of lapse rates of ground and elevated inversions (1974-78) at Visakhapatnam**

| Lapse rate (°C/km) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Dec-Feb | Mar-May | Jun-Sep | Oct-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **(a) 00 GMT** | | | | | | | | |
| 0-10° | 79.4 | 82.8 | 73.0 | 79.4 | 84.1 | 76.9 | 100 | 85.0 | 100 | 83.3 | 85.3 | 78.8 | 80.3 | 77.8 | 88.7 | 84.8 |
| 10-20° | 16.7 | 14.2 | 19.2 | 14.8 | 11.1 | 19.3 | 0.0 | 15.0 | 0.0 | 16.7 | 8.6 | 11.5 | 14.1 | 15.7 | 10.1 | 11.4 |
| 20-30° | 2.9 | 3.0 | 5.7 | 5.8 | 3.2 | 3.8 | 0.0 | 0.0 | 0.0 | 0.0 | 4.2 | 4.8 | 3.6 | 5.6 | 1.2 | 3.0 |
| 30-50° | 0.4 | 0.6 | 2.1 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 3.0 | 1.0 | 0.9 | 0.0 | 0.8 |
| >50° | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 1.0 | 0.0 | 0.0 | 0.0 |
| | | | | | | | | **(b) 12 GMT** | | | | | | | | |
| 0-10° | 87.5 | 82.5 | 84.0 | 68.2 | 78.9 | 91.7 | 100 | 100 | 92.0 | 92.8 | 77.4 | 79.0 | 83.8 | 76.4 | 95.0 | 80.4 |
| 10-20° | 5.3 | 17.5 | 13.2 | 23.8 | 12.3 | 8.3 | 0.0 | 0.0 | 8.0 | 0.0 | 22.4 | 15.3 | 11.5 | 16.4 | 5.0 | 15.2 |
| 20-30° | 7.2 | 0.0 | 1.4 | 4.8 | 7.1 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 0.0 | 1.9 | 3.4 | 4.1 | 0.0 | 4.4 |
| 30-50° | 0.0 | 0.0 | 1.4 | 3.2 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.8 | 1.3 | 2.1 | 0.0 | 0.0 |
| >50° | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

quency of inversions and isothermal layers for 12GMT (Table 5b) shows that March to June have high frequency in the range 501-1000 m.

### 3.3 *Nature and strength of inversion during consecutive ascents*

Generally inversions set in night and become intense just before sun rise and are lifted up after sun rise due to solar heating (Table 6). Inversions are non-existent at 1130 IST. Lapse rate in the inversions increases from mid night to early morning.

## 4. Mixing depth

An examination of percentage frequency of ground based inversions point out a sudden increase in December which continued till March. Since increase in inversion frequency tends to increase the occurrence of low morning mixing

**TABLE 4**

**Percentage frequency of occurrence of mean monthly ground inversions (1974 1978)**

| Range of ht. (m) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Dec-Feb | Mar-May | Jun-Sept | Oct-Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(a) 00 GMT** | | | | | | | | | | | | | | | | |
| 0-100 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| 101-200 | 11.1 | 8.3 | 14.8 | 9.0 | 7.1 | 00 | 00 | 00 | 00 | 14.3 | 00 | 27.7 | 15.0 | 11.5 | 00 | 6.7 |
| 201-300 | 72.3 | 62.5 | 11.1 | 8.1 | 14.3 | 55.6 | 00 | 14.3 | 00 | 57.1 | 50.0 | 33.3 | 56.7 | 11.4 | 25.0 | 53.3 |
| 301-400 | 11.1 | 16.7 | 14.8 | 27.0 | 28.6 | 22.2 | 00 | 57.1 | 37.5 | 14.3 | 37.5 | 27.7 | 18.3 | 21.4 | 37.5 | 26.7 |
| 401-500 | 5.5 | 00 | 18.5 | 28.6 | 28.6 | 00 | 00 | 14.3 | 50.0 | 14.3 | 12.5 | 00 | 1.7 | 23.0 | 20.8 | 13.3 |
| 501-1000 | 0.0 | 12.5 | 40.8 | 27.3 | 21.4 | 22.2 | 00 | 14.3 | 12.5 | 0.0 | 0.0 | 11.3 | 8.3 | 32.7 | 16.7 | 0.0 |
| >1000 | 0.0 | 0.0 | 0.0 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 |
| **(b) 12 GMT** | | | | | | | | | | | | | | | | |
| 0-100 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 20.0 | 00 | 00 | 00 | 00 | 00 | 16.7 |
| 101-200 | 00 | 00 | 11.1 | 00 | 11.1 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 10.5 | 00 | 00 |
| 201-300 | 100 | 100 | 11.1 | 00 | 11.1 | 16.6 | 00 | 00 | 40.0 | 40.0 | 100 | 00 | 66.7 | 10.5 | 21.4 | 50.0 |
| 301-400 | 00 | 00 | 11.1 | 00 | 33.4 | 50.0 | 100 | 33.4 | 00 | 40.0 | 00 | 100 | 33.3 | 21.0 | 42.9 | 33.3 |
| 401-500 | 00 | 00 | 22.3 | 00 | 0.0 | 16.7 | 00 | 33.6 | 60.0 | 00 | 00 | 00 | 00 | 15.8 | 21.4 | 00 |
| 501-1000 | 00 | 00 | 44.4 | 00 | 44.4 | 16.7 | 00 | 33.0 | 00 | 00 | 00 | 00 | 00 | 42.2 | 14.3 | 00 |
| >1000 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 00 | 0 | 00 |

**TABLE 5**

**Percentage frequency of mean monthly inversion and isothermal (1974-78)**

| Range of ht. (m) | Jan | Feb | Mar | Apr | May | June | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(a) 00 GMT** | | | | | | | | | | | | |
| 0-500 | 0.0 | 2.9 | 8.6 | 1.5 | 1.6 | 10.6 | 13.3 | 3.4 | 30.8 | 13.6 | 6.3 | 1.3 |
| 501-1000 | 13.6 | 43.5 | 69.9 | 53.7 | 48.4 | 52.6 | 20.0 | 65.5 | 46.1 | 27.3 | 14.6 | 14.1 |
| >1000 | 86.4 | 53.6 | 21.5 | 44.8 | 50.0 | 36.8 | 66.7 | 31.1 | 23.1 | 59.1 | 79.1 | 84.6 |
| **(b) 12 GMT** | | | | | | | | | | | | |
| 0-500 | 4.1 | 6.3 | 11.5 | 6.1 | 5.0 | 0.0 | 6.3 | 4.4 | 5.6 | 0.0 | 0.0 | 0.0 |
| 501-1000 | 23.3 | 50.8 | 70.5 | 67.7 | 66.2 | 64.7 | 25.0 | 47.8 | 44.4 | 25.0 | 7.9 | 18.0 |
| >1000 | 72.6 | 42.9 | 18.0 | 26.2 | 28.8 | 35.3 | 68.7 | 47.8 | 50.0 | 75.0 | 92.1 | 82.0 |

TABLE 6

**Nature and strength of inversion in consecutive ascents in a day**

| Time of Obs. Date (Jun78) | Time of Obs. Time (IST) | Ht. of inversion Bottom (m) | Ht. of inversion Top (m) | Ht. of inversion Thickness (m) | Strength (°C) | Lapse rate (°C/km) | Nature of inversion |
|---|---|---|---|---|---|---|---|
| 5 | 2308 | 374 | 600 | 226 | 0.2 | 0.9 | Elevated |
| 6 | 0530 | 385 | 637 | 252 | 3.2 | 12.8 | Do. |
| 6 | 1130 | No inversion | | | | | |
| 6 | 1845 | 254 | 478 | 224 | 0.2 | 0.8 | Do. |
| 7 | 0045 | 00 | 582 | 582 | 2.2 | 4.0 | Ground |
| 7 | 0530 | 386 | 808 | 422 | 2.6 | 6.2 | Elevated |
| 7 | 1715 | No inversion | | | | | |
| 7 | 2315 | 00 | 720 | 720 | 0.6 | 0.9 | Ground |
| 8 | 0601 | No inversion | | | | | |
| 9 | 2250 | 00 | 309 | 309 | 0.4 | 1.3 | Do. |
| 10 | 0550 | No inversion | | | | | |

*Temperature difference between the base and top of inversion

TABLE 7

**Percentage frequeucy of occurrence of days when**

| | Years 74 | 75 | 76 | 77 | 78 | 74-78 |
|---|---|---|---|---|---|---|
| **(a) Morning's Mixing depth ⩽ 500 m and transport wind speed ⩽ 4m/sec** | | | | | | |
| Dec | 53.3 | 45.2 | 56.7 | 80.0 | — | 58.7 |
| Jan | — | 46.7 | 51.7 | 46.4 | 58.1 | 50.8 |
| Feb | — | 39.3 | 78.2 | 46.1 | 74.0 | 58.6 |
| Mar | — | 34.5 | 53.6 | 30.0 | 71.4 | 45.4 |
| **(b) Afternoon's ventilation ⩽ 6000 $m^2$/sec and transport wind speed ⩽4 m/sec** | | | | | | |
| Dec | 43.3 | 35.5 | 33.3 | 36.7 | — | 37.2 |
| Jan | — | 30.0 | 31.0 | 35.7 | 38.7 | 33.9 |
| Feb | — | 35.7 | 34.8 | 26.9 | 48.1 | 36.5 |
| Mar | — | 13.8 | 17.9 | 16.7 | 29.4 | 18.2 |
| **(c) When both (a) and (b) occurred** | | | | | | |
| Dec | 30.0 | 29.0 | 20.0 | 26.7 | — | 26.9 |
| Jan | — | 13.3 | 17.2 | 25.0 | 29.0 | 21.2 |
| Feb | — | 10.7 | 34.8 | 7.7 | 44.4 | 24.0 |
| Mar | — | 34.0 | 17.9 | 13.3 | 23.5 | 13.4 |

depths which in turn lead to high air pollution potential (Padmanabhamurty and Mandal 1976). Therefore, in the present study mixing depths and ventilation coefficients during December-March only are examined.

Mixing depths are calculated utilizing Radiosonde data of Visakhapatnam according to Holzworth (1967) from December to March for the years 1974-1978, with due corrections to surface temperature.

The mean monthly morning and afternoon mixing depth and average transport wind through the mixing layer and ventilation coefficient from December to March for the years 1974-78 are represented in Fig. 1(a). Averaged over 4 years are shown in Fig. 1(b).

In general December is associated with minimum mixing depths. January is generally having maximum mixing depth because of comparatively less ground inversions. The average monthly morning mixing depth averaged for 4 years (Fig. 1b) is least in December (282 m) and maximum in January (425 m).

December has intense ground inversions although less frequent than February & March. An interesting feature at Visakhapatnam is that the morning mixing depths in general are ⩽ 500 m and morning transport wind speed ⩽ 4 m/sec. Afternoon mixing depth (Fig. 2a) show a large variation from December to March. They are generally low in March and December which is considered to be due to high per cent of inversions and isothermal layers in those months. In general high values of afternoon mixing depth are in January and February. Average afternoon mixing depth (Fig. 2b) attains a minimum value in March and maximum in February. Though March

TABLE 8

**Comparison of air pollution potential at Delhi and Visakhapatnam**

| | Delhi | | Visakhapatnam |
|---|---|---|---|
| 1 | Inland city with extremes of climate | 1 | Coastal town with moderate climate |
| 2 | High % of ground inversion in winter (Padmanabhamurty and Mandal 1978) | 2 | Low % of ground inversions. However, high % of elevated inversions and isothermal layers have rendered air pollution potential at Visakhapatnam high. |
| 3 | High % of ground inversions in the range 101-200 m | 3 | High % of ground inversions in the range 201-300 m |
| 4 | High % of inversions when the transport wind is > 4m/sec | 4 | They are associated with winds ⩽ 4 m/sec |
| 5 | Lapse rates > 50°C/cm are noticed | 5 | Such lapse rates are rare |
| 6 | Inversions are intense | 6 | Inversions are less intense |
| 7 | % frequency of ground inversions are marked in November (98%) | 7 | They occur in February (18.8%) |
| 8 | Morning mixing depths at Delhi are comparatively low (06-185m) | 8 | They are high (184-533m) |
| 9 | Higher upper winds and hence high ventilation coefficients | 9 | Low upper winds and hence low ventilation coefficients. |
| 10 | % frequency of days with scavenging rain is negligible in winter | 10 | Same as in Delhi |

has transport wind through mixing layer ⩾ 4m/sec low afternoon mixing depths reducing the ventilation.

**5. Ventilation coefficient**

Morning and afternon ventilation coefficients (Fig. 1) show that they vary from month to month and year to year similar to mixing depths. Afternoon ventilation coefficient is lower in December and January and high in March. Average morning and afternoon ventilation (Fig. 1b) show that February has recorded least morning ventilation, March highest and December least afternoon ventilation and March highest respectively.

**6. Analysis of morning mixing deph and transport wind through mixing layer and afternoon ventilation (1974-1978)**

The percentage frequency of occurrence of days when the morning mixing depth is ⩽ 500 m and transport wind ⩽ 4m/sec is found to be high for December and February and least for March and 50·8 per cent for January (Table 7 a).

The percentage frequency of occurrence of days when afternoon ventilation is ⩽ 6000 m²/sec and afternoon transport wind through mixing layer is ⩽ 4m/sec is high for December and February and least for March (Table 7b).

In Table 7(c) are shown both the morning's mixing depth when it is ⩽ 500 m and transport wind ⩽ 4m/sec and afternoon's ventilation ⩽ 6000 m²/sec and transport wind ⩽ 4m/sec Percentage frequency when both the above conditions satisfied are high in December and February and least in March. December, January and February have, therefore, high pollution potential at Visakhapatnam.

**7. Comparision of air pollution potential at Delhi and Visakhapatnam**

A comparative study of pollution potential at Visakhapatnam and Delhi are presented in the following Table 8.

Both Delhi and Visakhapatnam are faced with high air pollution potential though the meteorological conditions favourable to air pollution are different at these two places.

**8. Conclusion**

High percentage frequency of low based stable layers (elevated), low mixing depths with anticyclonic conditions light winds through the mixing layer and negligible precipitation during December-February suggest that pollution potential at Visakhapatnam is high. As ventilation coefficient is found to be very low during December-February, the pollutant concentrations are likely to be increased if they are released into the atmosphere.

December to February show high pollution potential according to the criteria of Gross (1970). Pollution control measures to alleviate the problem have to be taken during this period.

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