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Dispersal Conditions and Assimilative Capacity of Air Environment at Gajuwaka Industrial Hub in Visakhapatnam

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ABSTRACT

The comprehension of a pollution event requires not only the accurate determination of the chemical composition of the atmospheric particles but also the elucidation of the role played by the dilution properties of the lower atmosphere. In this context, a rapidly growing Gajuwaka industrial hub in Visakhapatnam was chosen for estimating the assimilative capacity of air environment for its pollution potential by calculating the ventilation coefficient values. The diurnal variations of assimilation capacity of atmosphere were shown high during the noon hours and low at night and early morning hours in all the seasons. The monthly variations of low and high assimilative capacities were observed in the month of February and October respectively. Seasonally, post-monsoon showed high ventilation capacity followed by monsoon, winter and pre-monsoon seasons. Further, this is compared with the seasonal variations of the ambient air quality at the study area. The study area met the criteria of low pollution potential for all the time except for morning hours. The study area exhibited 'good' category dispersal conditions with an annual mean of ventilation coefficient value of 4271.6m2s-1 and the duration of 'good' dispersal conditions are longer in the months of April, May and June compared to other seasonal months.

Keywords: Pollution potential, Ventilation coefficient, Mixing heights, Transport winds

I. INTRODUCTION

Urbanization and industrialization growth at any stage has direct impact on the surrounding air quality due to prevailed pollutants. The increase in the air concentration of a pollutant, in fact, is the result of the combination of the emission (and/or production) of the pollutants in the atmosphere and of the reduced capacity of the atmosphere to dilute them *[1]*. In the present situation of developmental activities, when new industries are coming up and the existing ones increasing their capacities, it is necessary to study the assimilative/healing capacity of the particular area to estimate the carrying capacity. The assimilative capacity of the atmosphere gives roughly an idea of the extent to which the atmosphere is capable of sustaining the pollution load from various emission sources *[2]*. Application of meteorological phenomena is well known to determine the assimilative capacity for a locality. The assimilative capacity of the atmosphere is determined in terms of ventilation coefficient, which is the product of two meteorological parameters, mixing height and average wind speed through mixing heights (transport wind speed). The assimilative capacity of the atmosphere is directly proportional to the ventilation coefficient and inversely proportional to the pollution potential *[3]*. Dispersal conditions of pollutants at coastal regions are of great concern because of typical meteorological features of the lower atmosphere. Understanding the dispersal conditions and assimilative capacity of air environment can be useful for planners/technologists to mitigate air pollution events. In view of the above, rapidly growing Gajuwaka industrial hub of Visakhapatnam was chosen for the present study.

A. *Topography and Prevailing Meteorology of the Gajuwaka Industrial Hub – The Study Area*

It is located on the south of Visakhapatnam city in between 17^0 34'00" N to 17^0 42'00" N latitudes and 83^0 06'00" E to 83^0 14'00" E longitudes were chosen for the present study. The present study area is not situated in the bowl area of Visakhapatnam. The study area has seen rapid industrialization and tremendous population growth during the last few decades. It is spread over an area of 97 km^2 with a total population of about 3,70,000 (provisional figures of 2011 census) and with a semi urban and rural atmosphere. The study area encompasses with a thermal power plant, upcoming pharma city, an integrated steel plant, a minor port, a number of associated ancillaries and bound in the east by the Bay of Bengal (Fig.1). The topography of the area is from plain to undulating with small hillocks. Yarada hill range stretches from E to WNW and NW of the study area with a maximum altitude of about 360m. The climate is warm and humid. This area experiences two spells of rainfall during the southwest and northeast monsoons. In addition, this area is subjected to on an average two to three low pressure depressions (sometimes intensified to cyclonic storms) which results in moderate to heavy rains. The winds are north-northeasterly during the winter season while during the summer they are west- southwesterly and variations in wind directions were observed due to the effect of land and sea breeze. Wind speed is quite high with predominant wind direction of WSW followed by W and SW. Diurnal variation in wind speed showed that the speed was high during daytime reaching a maximum at around 14:00–16:00hrs and gradually decreasing with nightfall reaching a minimum at midnight. A maximum calm conditions frequency of 73% was observed at 04:00hrs during winter season.

II. METHODS AND MATERIAL

For ventilation coefficient calculations, surface wind speed data were collected from the weather monitoring station located in the study area and monthly averages of hourly observations of mixing heights (Z_1) were obtained from the reports (the data of Visakhapatnam) of National Environmental Engineering Research Institute, Nagpur *[4]* as the study area specific mixing heights were not available and the data of Visakhapatnam was adopted which is very close (16kms) to this study area. Then the monthly averages of hourly wind speed observations based on available data during three years period (2008-2010) have been calculated for monthly averages of hourly transport wind speed (U_1) by applying the wind profile (power) law *[5]*.

Ventilation Coefficient (m^2s^{-1}) = Z_1U_1

Where

Z_1 = mixing height,

U_1 = average wind speed in the mixed height (transport wind speed).

By applying the above equation, hourly, monthly with seasonal and annual ventilation coefficients have been calculated for the study area. Further, the following criteria have been considered to delineate the pollution potential for this present study;

1) The US National Meteorological Centre and Atmospheric Environment Services, Canada, has classified that high pollution potential occurs when the afternoon ventilation coefficient is <6000m^2s^{-1} and transport wind speed does not exceed 4m/s and during morning hours, the mixing height is <500m and transport wind speed does not exceed 4 m/s and the winds at a height of 1500m must average less than 10m/s *[6, 7]*.
2) The air pollution dispersion index (ventilation index) which is proposed by the State of Colorado Department of Health in Denver is used to categorize as POOR: 0-2000m^2s^{-1}, FAIR: 2001-4000m^2s^{-1}, GOOD: 4001-6000m^2s^{-1} and EXCELLENT: >6001m^2s^{-1} *[8, 9]*. Lower values of ventilation coefficient indicate less dispersion potential of pollutants where as higher value designates the capacity of the atmosphere to disperse the pollutants.

Keeping in view the importance of the study area, ambient air quality monitoring was carried out at some selected residential colonies during winter and summer seasons for a period of two years (2008-2010). Subsequently, the measured data of six criteria air pollutants were converted into an Indian air quality index (IND-AQI) recently developed by CPCB, New Delhi, (http://home.iitk.ac.in/~mukesh/air-quality/Basis.html) to compare the seasonal variations of the air quality with respect to assimilative capacity of the study area.

III. RESULTS AND DISCUSSION

The calculated monthly averages of hourly ventilation coefficients (VC) values and the related mixing heights during different seasons were presented in figures 2 - 13.

Further, monthly and seasonal variations of ventilation coefficient values were presented in Fig. 14 to delineate status of the study area. Seasonal and annual frequency of hourly dispersal conditions at the study area was presented in Fig. 15 to appreciate the pollution potential. Annual mean of IND-AQI values and seasonal variations of pollutants at the study area were shown in Fig.16 and 17 respectively.

A. Ventilation coefficient (VC) values during pre-monsoon period

From the above figures, it can be noted that the fall of ventilation coefficient values at the time of noon hours was leading to high pollution potential for a short while. Again, the increase of values revealed the good dispersal conditions at the study area. These fluctuations can be attributed to the meso scale meteorological features at the study area. Higher and lower values were observed during 08-09:00 and 03-06:00hrs respectively. On an average, the month of May exhibited 'good' dispersal conditions (4514.8m^2s^{-1}) when compared with the other two months showing 'fair' dispersal conditions.

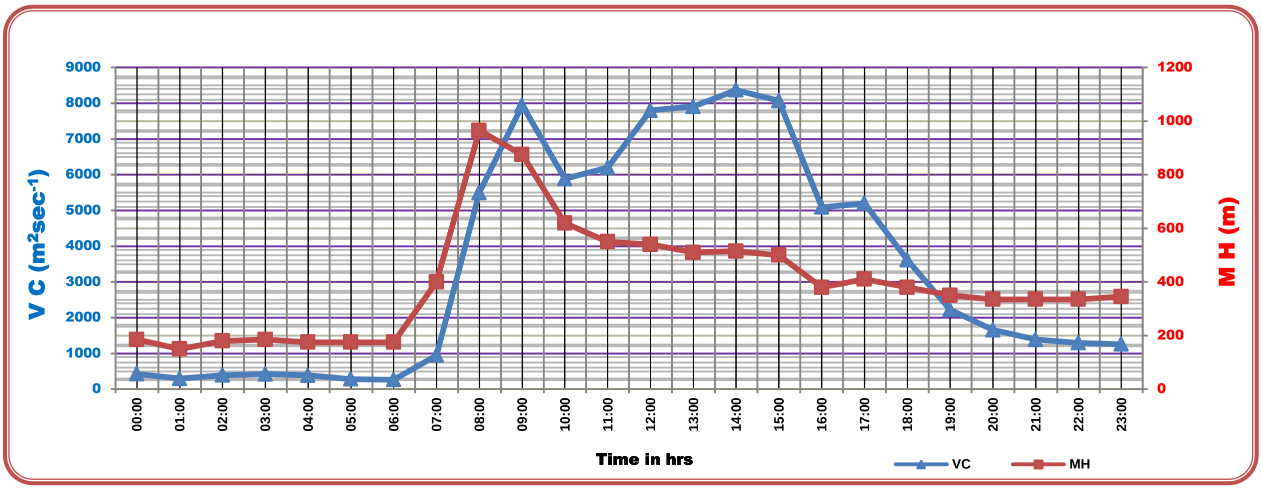

Fig. 2: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of March.

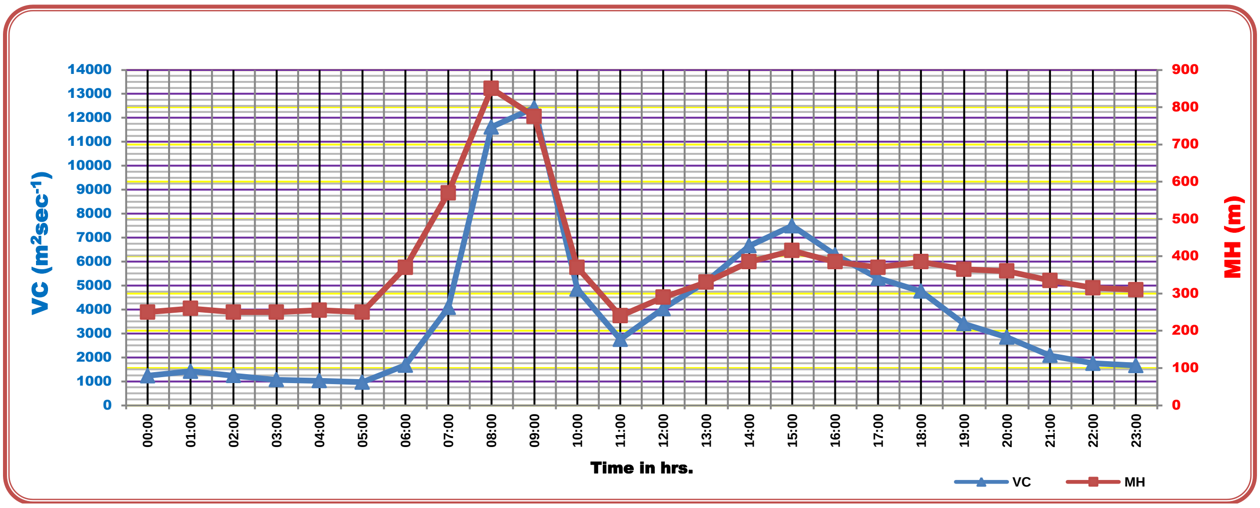

Fig. 3: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of April.

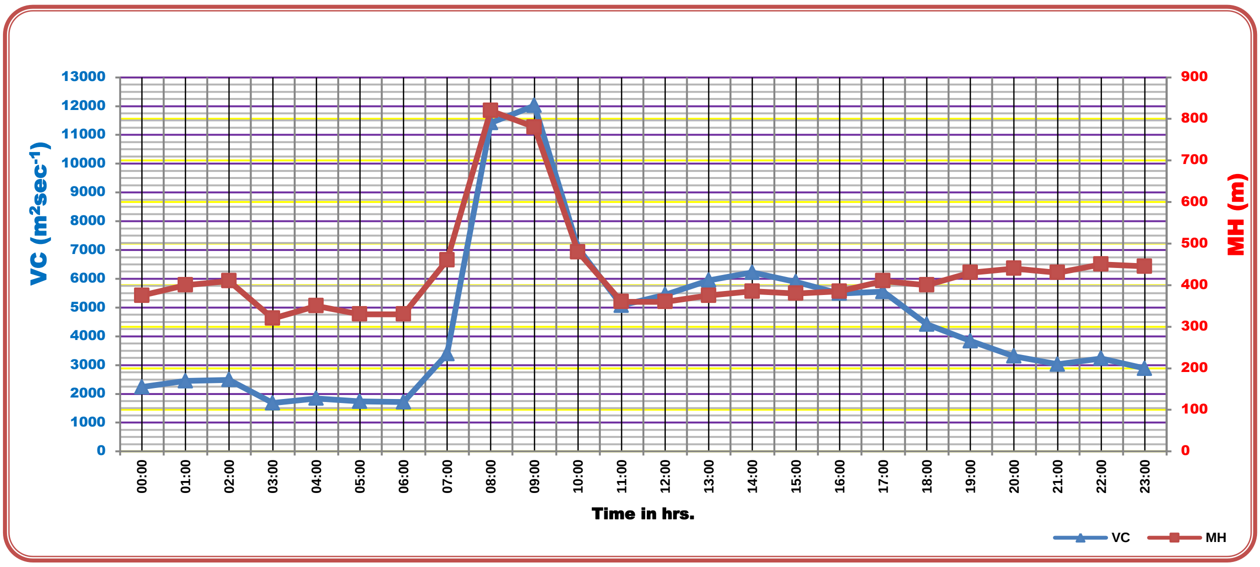

Fig. 4: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of May

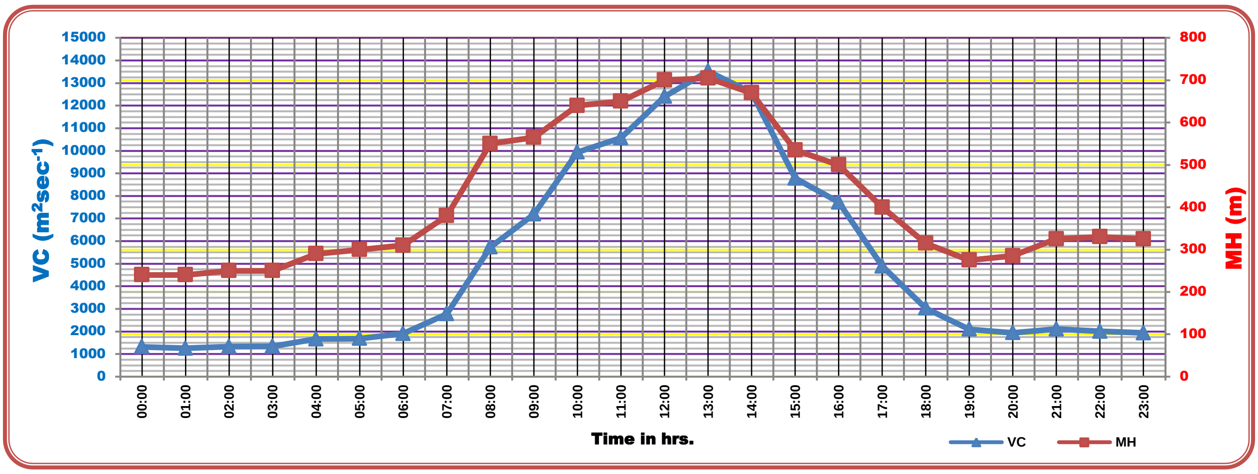

Fig. 5: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of June.

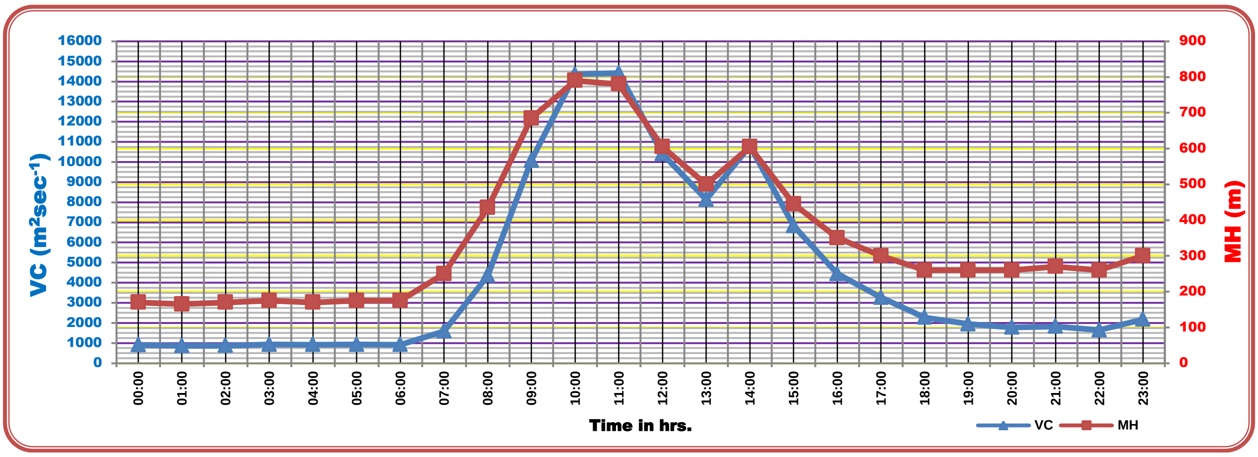

Fig. 6: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of July.

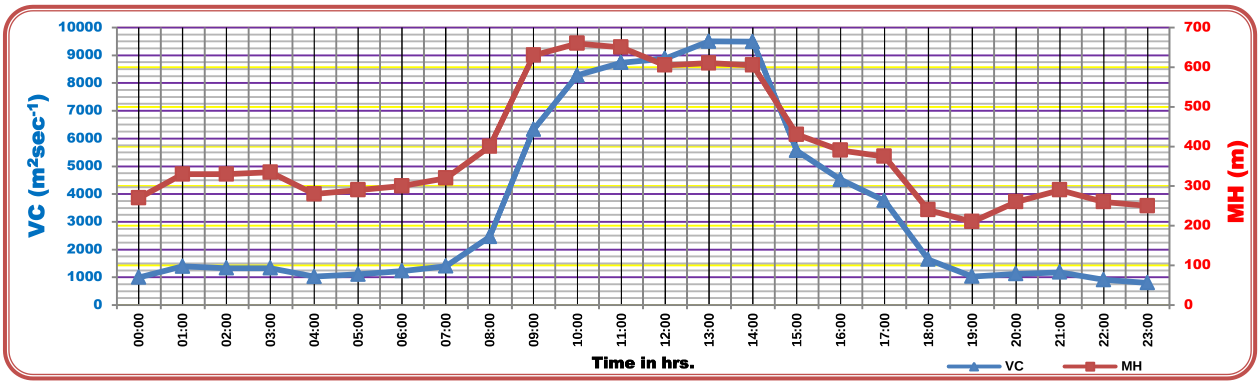

Fig. 7: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of August.

B. Ventilation coefficient (VC) values during monsoon period

On an average a maximum of 11241m^2s^{-1} and a minimum of 1074m^2s^{-1} VC values were observed during 11:00 and 00:00hrs respectively. Further, this period is influenced by the prevailing south-west monsoon and synoptic winds in dispersal of pollutants. The fall and raise of values in the month of July can be interpreted as a feature of arid conditions (Fig. 6).

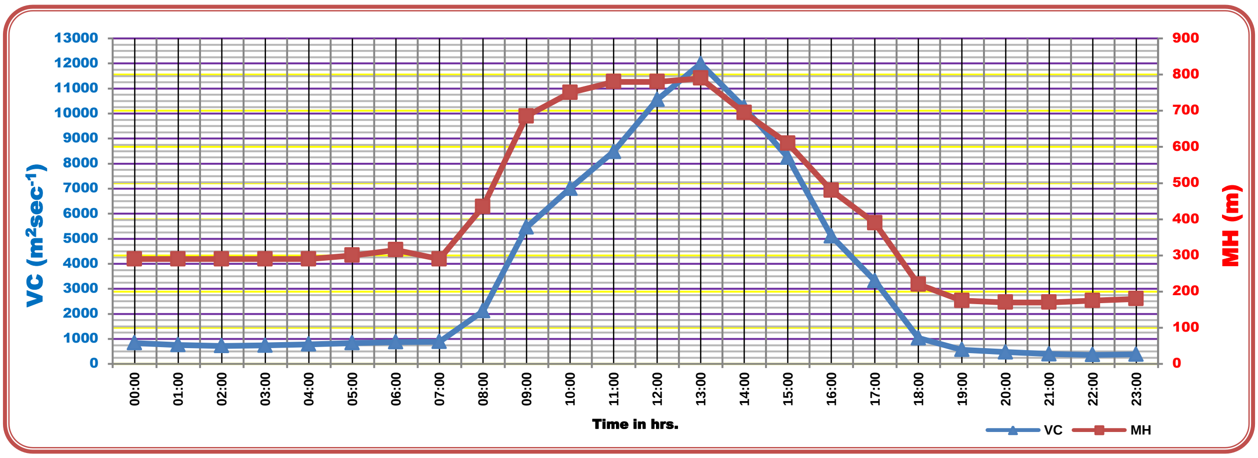

Fig. 8: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of September

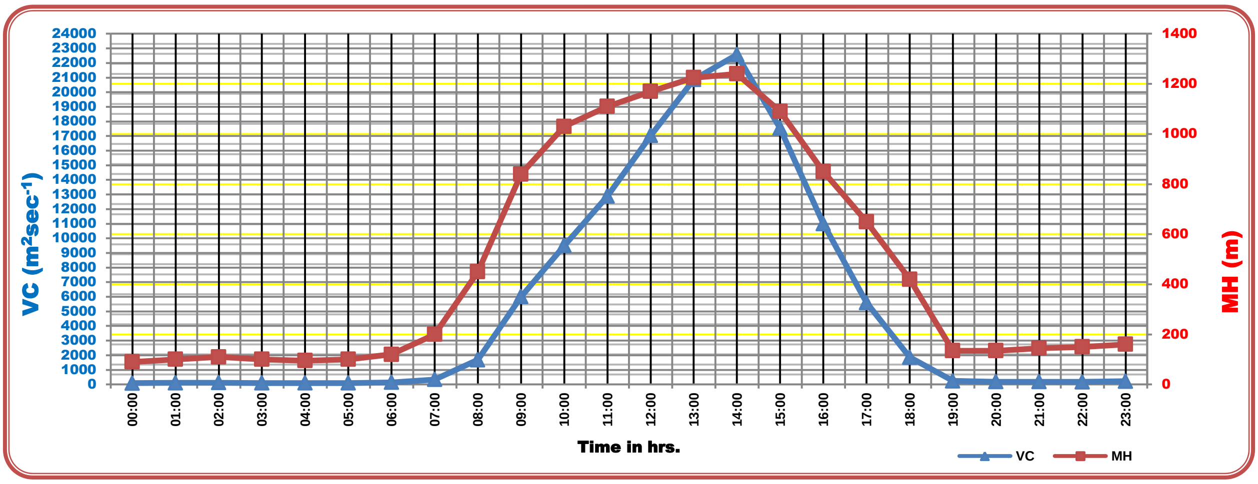

Fig. 9: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of October.

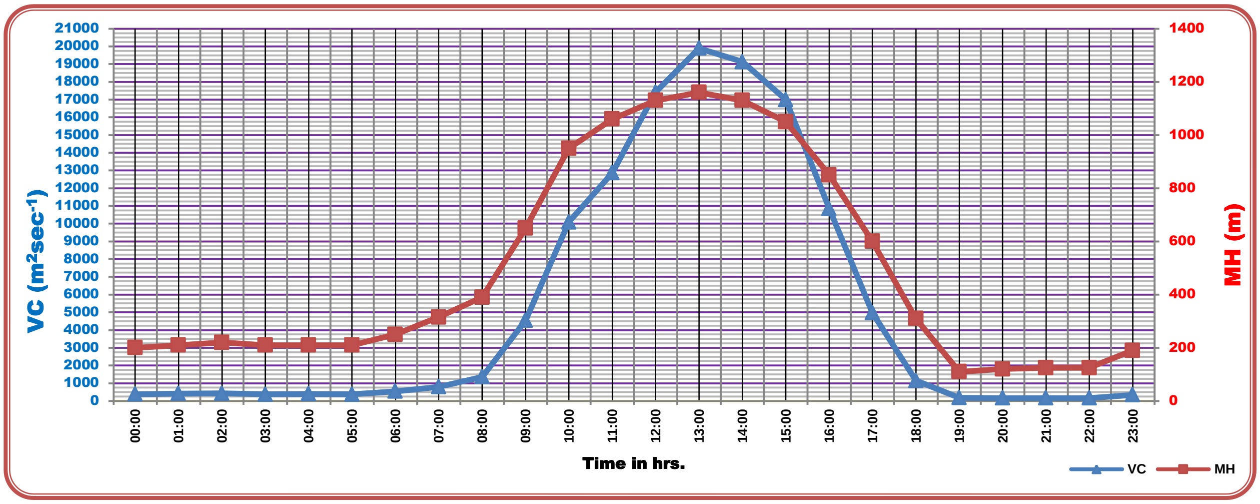

Fig. 10: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of November.

C. Ventilation coefficient (VC) values during post-monsoon period

Even though this season exhibited higher values ($4651.1 m^2s^{-1}$), 'Fair' dispersal conditions prevailed in the month of September ($3425 m^2s^{-1}$). Interestingly, the maximum $22572 m^2s^{-1}$ and the minimum $84 m^2s^{-1}$ values of the entire study are observed in the month of October. This might be attributed to abrupt meteorological features of the coastal area.

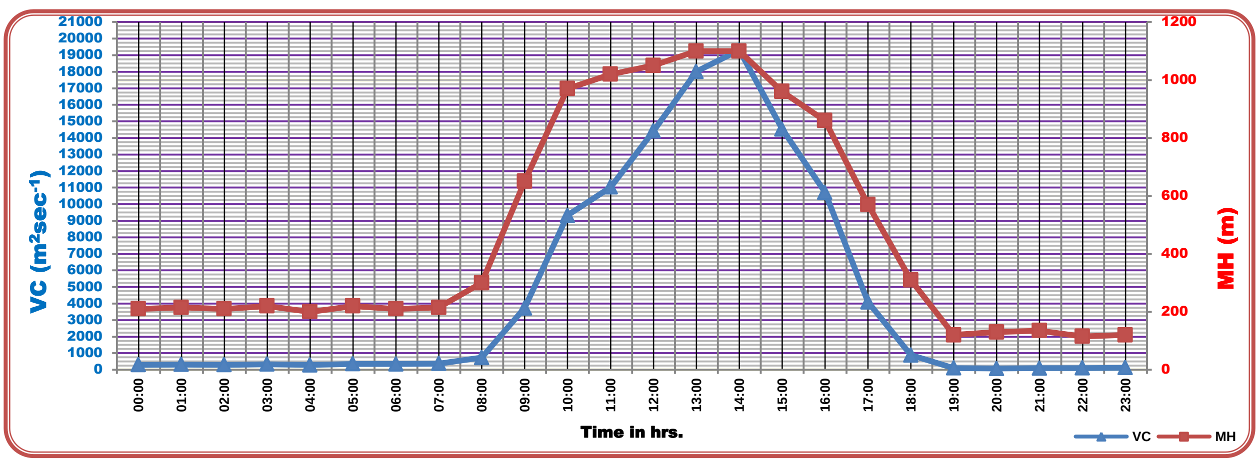

Fig. 11: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of December.

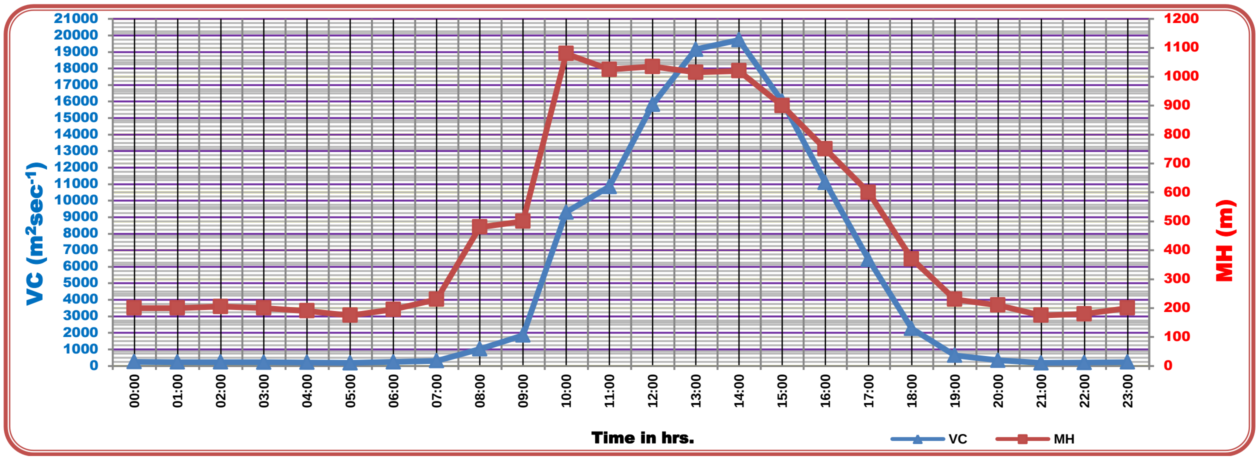

Fig. 12: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of January.

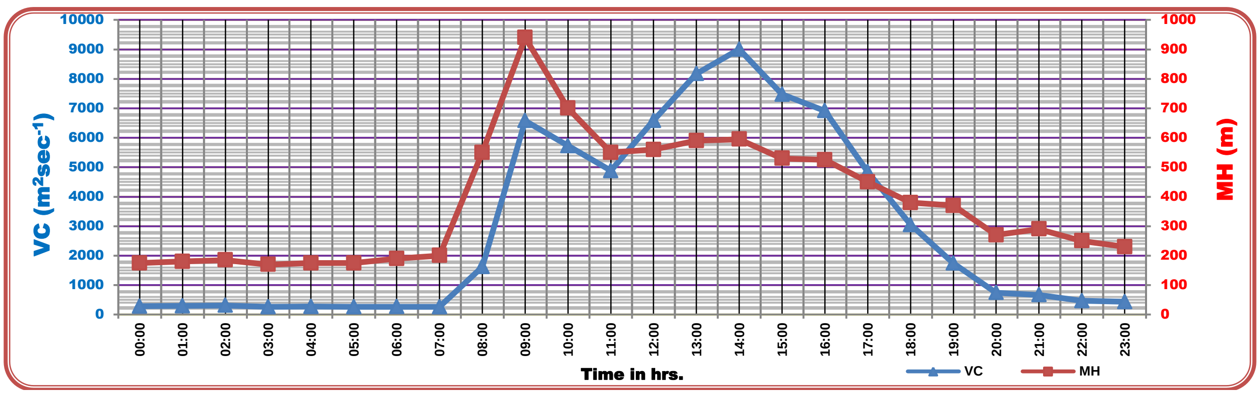

Fig. 13: Averages of hourly ventilation coefficient (VC) & mixing height (MH) values in the month of February

D. Ventilation coefficient (VC) values during winter period

From the above figures, 'Poor" dispersal conditions were observed during 19:00 to 08:00hrs throughout the season indicated the inversion and calm conditions at the study area. On an average, these winter months showed 'good" dispersal conditions during noon hours when compared with the monsoon and pre-monsoon seasons. Even though, January month showed higher value of ventilation coefficient than the pre-monsoon months but the duration of 'good' dispersal conditions is less for the month of January.

E. Assimilative capacity of the study area

It increases slowly from late morning hours and reaches peak levels in noon hours and again decreases from late evenings to night hours reaching very low in late night and early morning hours. Similar observations were made at Kochi of India *[10]*. The diurnal variations of ventilation coefficients revealed the low mixing heights and low wind condition during night and early morning hours. The low ventilation coefficient values during night and early morning and ground based inversions together lead to 'poor' assimilative capacity. From the data remarkable dispersal conditions were observed during the day from a total period of about 8 to 11 hours with short and longer spells in winter and pre-monsoon months respectively. According to which the period from 09:00 – 17:00 hrs is potentially safe for the dispersion of the pollutants.

1) *Criteria for the pollution potential:* From the figures 2 to 13, it is evident that the meteorological scenario of the study area satisfies the criteria for the pollution potential laid by the US National Meteorological Centre and Atmospheric Environment Services, Canada, except morning hours mixing heights of <500m throughout the year. This implies restricted vertical dispersion in late night and early morning hours. But, the possibilities of stagnating conditions at the study area are very less because of the prevailing horizontal dispersion due to the land breeze circulation in addition to the synoptic wind direction towards the coast especially in the months of March to August. Further, the marginal values of afternoon ventilation coefficient in the months of April and May are lead to high pollution potential for a short while in spite of high wind speeds. This can be attributed to the lower values of mixing heights due to the ground based inversions. Similar observations were made by *[3]* Rama Krishna et al., (2004). The maximum values of afternoon (22572m^2s^{-1}) and morning (1909m^2s^{-1}) ventilation coefficients were observed in the months of October and June respectively (Fig. 2-13). The monthly variations of ventilation coefficients showed (Fig.14) a minimum value in February month (2963.7m^2s^{-1}) increased slowly up to the month of June (4988.4m^2s^{-1}) and again started declining up to September (3424.8m^2s^{-1}) and reached the peak value in the month of October (5361.4m^2s^{-1}) followed by November month (5167.2m^2s^{-1}). The lowest value in the month of February was likely due to the high frequency of ground based inversions with slight solar insolation on day time and low winds and elevated calm conditions at night time. Further, high ventilation values (Fig. 14) were observed in post-monsoon season (4651.1m^2s^{-1}) followed by monsoon and winter seasons (4310.8 and 4139.5m^2s^{-1}) respectively and lowest values in pre-monsoon season (3985.1m^2s^{-1}) which was contrary to general expectations. Though strong winds were prevailed in the pre-monsoon season, the season recorded lowest ventilation coefficient values because of low mixing heights.

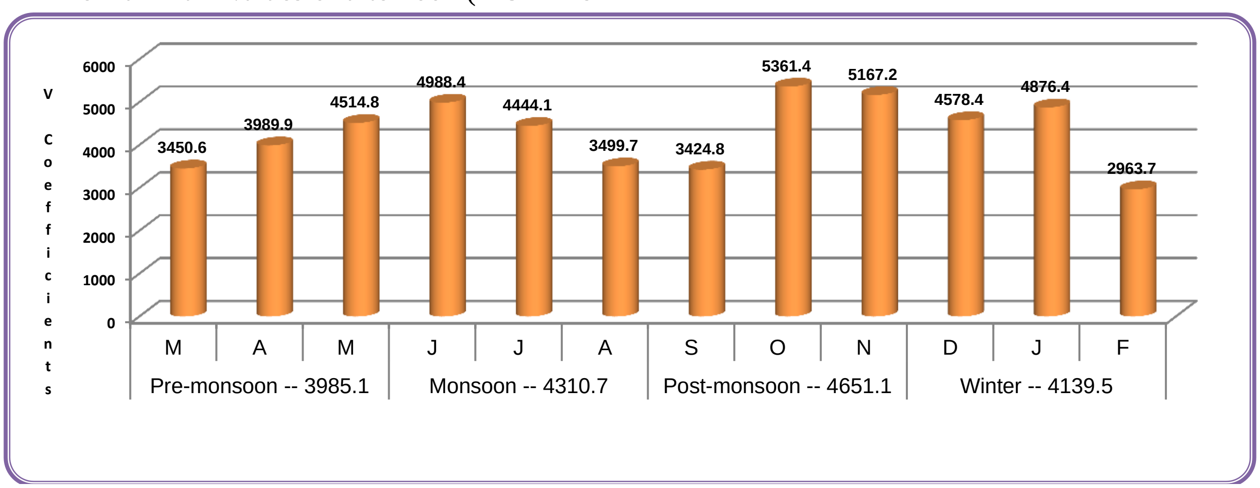

Fig. 14: Monthly & Seasonal variations of Ventilation Coefficient (m^2sec^{-1}) at the study area.

2) *Criteria for air pollution dispersion index:* According to air pollution dispersion index proposed by the State of Colorado Department of Health in Denver, the study area exhibited 'good' category dispersal conditions with an annual mean of ventilation coefficient value of

$4271.6 m^2 s^{-1}$ and except pre-monsoon season ('fair'), rest of the seasons were categorized as 'good' dispersal conditions (Fig. 14). But the seasonal frequency of occurrence of hourly dispersal/ventilation conditions was showing different trends (Fig. 15). The maximum 'poor' dispersal conditions were observed in post-monsoon and winter seasons (61.1%) followed by monsoon season (48.6%) and a minimum of 34.7% was observed in pre-monsoon season. 'Good' (23.6%) and 'fair' (20.9%) conditions were dominated in the pre-monsoon season compared to other seasons (Fig. 15). 'Poor' dispersal conditions are very less in the month of May (16.7%) when compared with the other months. The extreme conditions of 'excellent' and 'poor' (Fig. 15) categorization at the study area (except in pre-monsoon season) were corroborated the changes of abrupt coastal meteorological features at the study area.

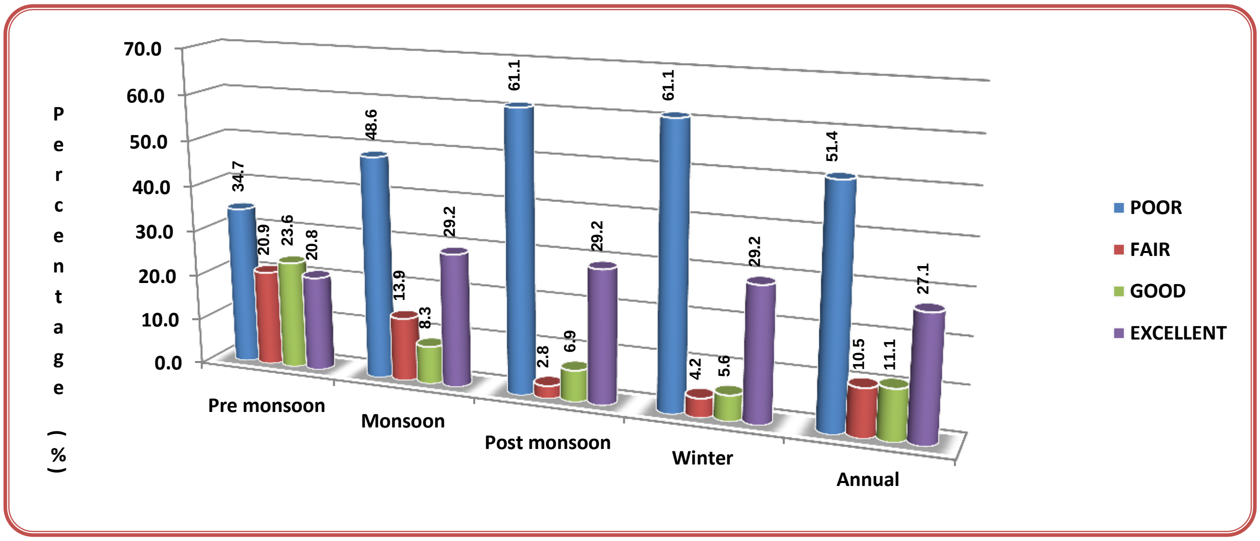

Fig. 15: Seasonal and annual frequency of hourly dispersal conditions at the study area.

F. *Comparison of ambient air quality (IND-AQI) indices with ventilation coefficient based air pollution dispersion index*

Even though, the study area exhibited annual frequency of 51.4% 'Poor' dispersal conditions but it has been observed that ambient air quality on the basis of IND-AQI scale category, the study area has fallen under 'moderate' category with the annual mean value of 112.2 (Fig. 16). The results revealed that the seasonal mean of air quality index values were varied from 60.2 to 143.3 and 82.8 to 226.5 in winter and pre-monsoon seasons respectively. This can be well compared with the ventilation coefficient values of winter ($4139.5 m^2 s^{-1}$) and pre-monsoon ($3985.1 m^2 s^{-1}$) of the present study. Further, gaseous pollutants and RSPM were found to be higher in winter season whereas TSPM is high in pre-monsoon season (Fig.17). According to present study, this can be attributed to the ground based inversions in winter and strong winds and low mixing heights in pre-monsoon season. The ambient air quality at the study area was 'moderate' according to IND-AQI (Fig. 16) whereas the dispersal conditions at the study area were 'poor' according to the air pollution dispersion index (Fig. 15). This anomaly might be due to the topographical and the meteorological parameters of the study area which ultimately leading to better diffusion of pollutants. In addition to the sea/land breeze regimes of coastal area, favorable wind directions towards coast (most of the time from WSW followed by W and SW), two spells of rain fall during the southwest and northeast monsoons

(78% of the total annual rain fall from June to October), two to three low pressure depressions/cyclones (mostly in November and May), appreciable relative humidity with foggy nature (wet deposition) in January and February months were the favorable natural ventilation ability of the study area.

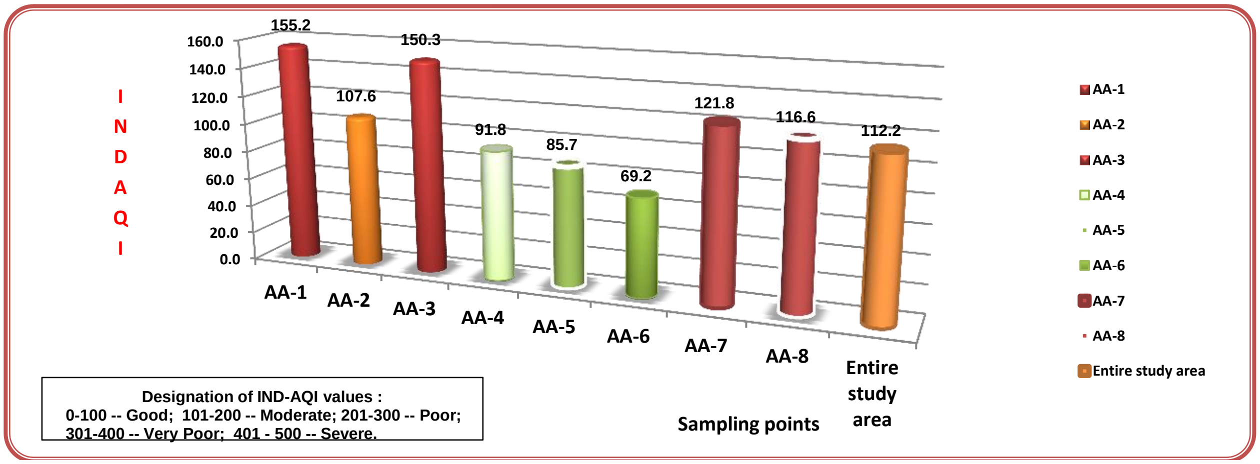

Fig. 16: Annual mean of IND-AQI values during study period.

From the Fig. 14, it has been observed that even though pre-monsoon months are showing less ventilation coefficient values compared to other seasons but the duration of 'good' dispersal conditions are longer (Fig. 2 to 4) when compared to other seasonal months and it can be attributed to the prevailed strong winds and strong solar insolation conditions. Overall, pre-monsoon months were showing better assimilative capacity at the study area when compared to other seasonal months in spite of minor differences in pollution dispersal conditions exhibited in hourly, monthly, seasonal and annual cycles.

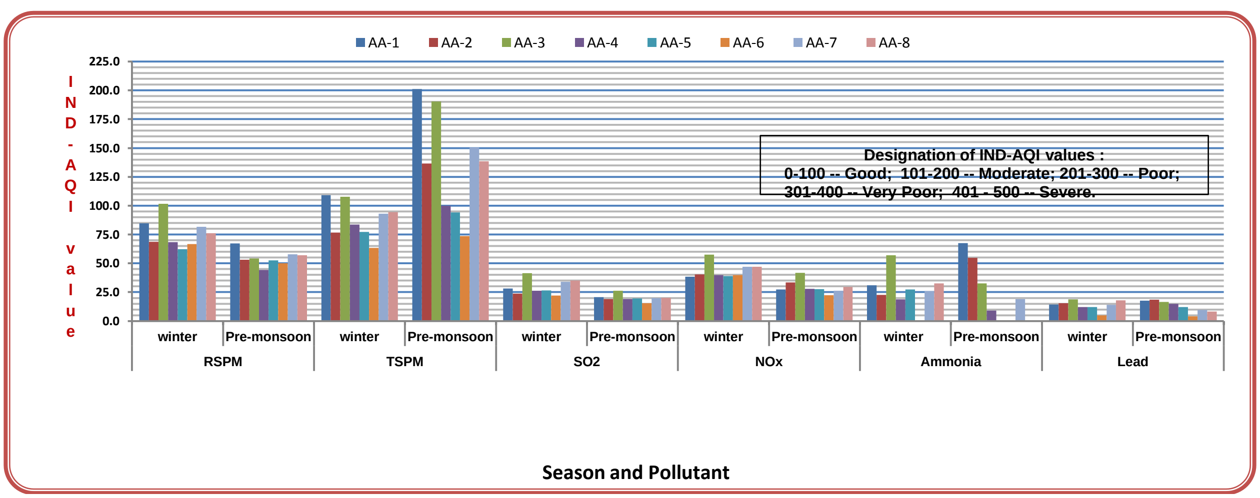

Fig. 17: Seasonal variations of pollutants at the study area in the form of IND-AQI (subindices).

IV. CONCLUSION AND RECOMMENDATIONS

From the above study, it can be concluded that the assimilative capacity of air environment of the study area was good with natural ventilation ability and without any stagnation of pollutants except during early morning hours. It is recommended to initiate necessary steps/strategies to prevent the release and exposure of emissions during risk hours.

V. REFERENCES

[1] Prashant Gargava. 1996. Industrial Emissions in a Coastal region of India: Prediction of Impact on Air Environment. Environment International. 27(3), 361-367.

[2] Pramila Goyal., Anand, S., and B.S. Gera. 2006. Assimilative capacity and pollutant dispersion studies for Gangtok city. Atmospheric Environment. 40, 1671-1682. Doi:10.1016/j.atmosenv.2005.10.057.

[3] Rama Krishna, T.V.B.P.S., M.K. Reddy., R.C. Reddy and R.N. Singh. 2004. Assimilative capacity and dispersion of pollutants due to industrial sources in Visakhapatnam bowl area. Atmospheric Environment. 38, 6775-6787.

[4] NEERI, 2003. Ambient air survey and air quality management plan for Visakhapatnam bowl area. National Environmental Engineering Research Institute. Nagpur. India.

[5] Padmanabha Murthy, B. 2004. Environmental Meteorology. I.K. International Pvt. Ltd., New Delhi.

[6] Edward Gross. 1970. The National Air Pollution Potential Forecast Program. Technical Note: 70-9. Environmental Technical Applications Center. Washington. D.C. pp.12-13.

[7] Stalkpole, J.D., 1967. The Air Pollution Potential Forecast Programme. ESSa Tech., Memo. WBTM-NMC 43.

[8] Deniz Derya Genc., Canan Yesilyurt., Banu Bayar and Gurdal tuncel. 2005. Effects Of Meteorology On Ankara Air Quality. Proceedings of the Third International Symposium on Air Quality Management at Urban, Regional and Global Scales. 26-30 September 2005, Istanbul – Turkey.

[9] Eagleman, J.R. 1991. Air pollution meteorlogy. Kansas: Trimedia.

[10] Goyal, S.K. and C.V. Chalapati Rao. 2006. Air assimilatie capacity-based environment friendly siting of new industries - a case study of Kochi region, India. Elsevier Ltd., doi:10.1016/j.jenvman.2006.06.020.