# Pollution Contribution from Line Sources and Carrying Capacity of the Environment at Hinkal Junction, Mysuru

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*Abstract*— **Air quality in urban areas is polluted due to vehicular and industrial emissions which may cause a negative impact on human health. This paper focuses on traffic density with its composition in Hinkal Junction, Mysuru and identification of nitrogen oxides ($NO_X$), carbon monoxide (CO), particulate matters (PM), carbon dioxide ($CO_2$) and hydrocarbon (HC) pollution load from two-wheeler (2W), three-wheeler (3W), light duty vehicle (LDV) and high duty vehicle (HDV) and their dispersion over the study area with the help of various meteorological factors. Windrose plot represents a predominant wind was blowing from East to West direction and from West-South-West towards East-North-East direction. The traffic density studies showed a maximum traffic density during 08:00-10:00 hrs and 18:00-20:00 hrs, with Emission Factors (EFs) for $CO_2$ varying from 300 – 600 g/mi followed by CO and HC from 5–12 g/mi and 1–3 g/mi, respectively. Traffic distribution was dominated by 2W (~61%), followed by 4W (15%), HDV (12%), LDV (8%) and 3W (4%). From EF study, it was observed that NOx was mainly contributing from HDV (74%) followed by 2W (13%), LDV (8%), 3W and 4W (2-3%). A similar observation was made for $PM_{10}$ and $CO_2$ pollutants also. However, the ventilation coefficient (VC) studies showed very low (<2000 $m^2/s$) during morning (01:00–08:00 h) and evening/night hours (23:00–24:00 h) indicating low assimilative capacity or high pollution potential during these periods.**

***Keywords***— ***Dispersion, Emission Factor, Windrose, Ventilation Coefficient, Traffic Density***

## I. INTRODUCTION

The continuous and rapid growth in population, urbanization, industrialization and transportation in India, in recent years have caused tremendous damage to the environment [1]. Road intersections are more contaminated due to large variations in traffic, such as traffic flow (free, interrupted or congested), vehicular state (idle, acceleration, deceleration, cruise, etc.), vehicle type (cars, buses, trucks, etc.) [2,3]. The emission from industry and vehicles are typically composed of a mixture of NOx and $SO_2$ [4]. In the last three decades, the number of motorized vehicles in India has increased 29-times, from 1.9 million in 1971 to 55.0 million in 2001 [5]. The increase in vehicular number was not uniform for all types of vehicle; it was 7-fold for buses, 9-fold for trucks, 10-fold for car, Jeeps and taxis, however, a remarkable 67-fold for two-wheelers was noticed [5]. Vehicles in major metropolitan cities are estimated to account for 70 % of CO, 50 % of HC, 30 - 40 % of NOx, 30 % of SPM and 10 % of $SO_2$ of the total pollution load of these cities, of which two-third is contributed by two wheelers alone [6]. However, Prakash et al. (2017) [7] reported line sources were more contributing in Hebbal Industrial area, where NOx and $PM_{10}$ were contributing ~86% and ~68% from line sources and ~14% and ~32% from point sources, respectively. A similar result was obtained from Karuna et al. (2017) [8], where 2W vehicles were found to be maximum in the traffic distribution which was varying from 50–60 % (12000–17000 vehicle per day (VPD)) followed by HDV and LDV ranging from 6–15 % (2000–5000 VPD). The aim of the present study is to identify the traffic density in one of the traffic congested roads in Mysuru, i.e., Hinkal Junction, which is well connected with industrial area and city region. However, an attempt has been made to identify the pollution load in terms of emissions and the possible dispersion over the nearby area with the help of meteorological data.

## II. STUDY AREA

### *Study Area*

Mysore district is one of the tourist destinations, in Karnataka, India, with a population of about 10.25 lakhs. The present study was conducted near to the Hinkal junction where four major roads are connected to each other (Fig. 1). The location was selected because of the presence of heavy traffic density throughout the day, which may cause air pollution to the nearby areas. The road is well connected with Mysuru city, Bogadhi, Hootagally industrial area and Hebbal industrial area. Due to this reason, most of the Heavy-Duty Vehicles (HDV) pass through this road for carrying the raw materials and supplying the finished product to various places. It was observed that, a densely populated residential area is placed at the East and South direction of the study area. Moderately populated area is place in West and North direction of the study area.

## III. RESULTS AND DISCUSSION

### *Meteorological Data*

Air pollutants dispersion depends on various meteorological factors such as, wind velocity, wind direction, temperature, relative humidity and precipitation. The hourly meteorological data was collected from the website www.wunderground.com. Hourly meteorological data was used to understand the monthly variation of meteorological factors (Table 1). Maximum temperature was found to be 37°C in the month of April, 2018 (summer season) and a minimum temperature of 15°C was noticed in the month of February, 2018 (winter season). The average temperature was varying from 24°C to 28°C during the study period. Further, a maximum relative humidity (RH) was found to be 97% in the month of January and February, 2018 and a minimum relative humidity of 18% was noticed during the month of March, 2018. However, maximum precipitation was observed during the month of June and July (45 mm). Windrose plot was prepared to understand the predominant wind direction and velocity over the study area. It was observed that, a maximum of velocity of 7.7 m/s in the month of May and June, 2018 and a minimum of 0.5 m/s in January, March and December, 2018. Maximum wind was blowing from East to West direction and West-South-West towards East-North-East direction (Fig. 2.).

The direction in windrose diagram represents, the wind will carry the pollutants from the upwind direction to the downwind direction. The frequency distribution of wind speed represents 2-3 m/s wind frequency was 24.9 % followed by 3-4 m/s (20 %) and 1.5-2 m/s (16.4 %).

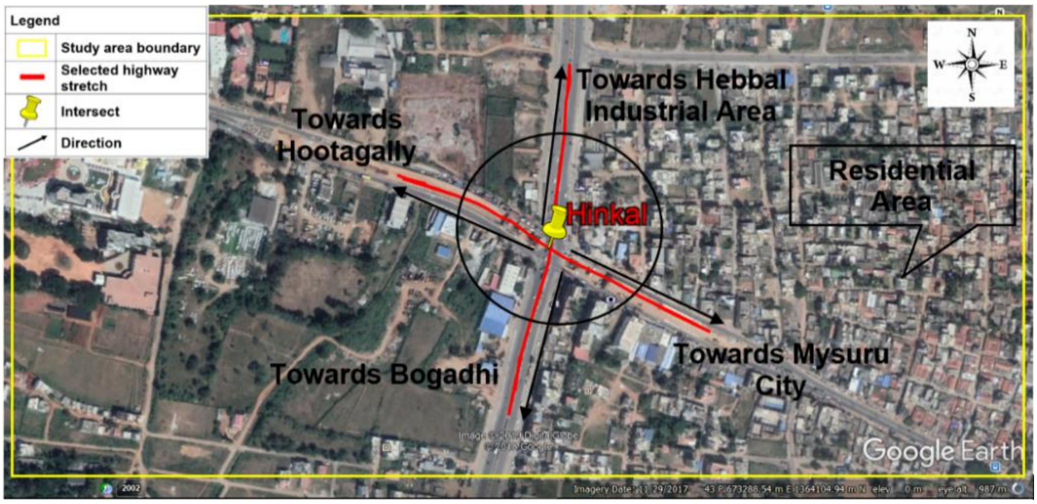


Fig. 1. Study area showing the Hinkal traffic junction intersect.

TABLE I. METEOROLOGICAL DATA FOR MYSURU CITY FOR 2018

| Month | Max Temp (°C) | Min Temp (°C) | Max RH (%) | Min RH (%) | Max WS (m/s) | Min WS (m/s) | Wind Direction | Max ppt (mm) |
|---|---|---|---|---|---|---|---|---|
| **JAN** | 30 | 18 | 97 | 25 | 5.8 | 0.5 | E | 0 |
| **FEB** | 31 | 15 | 97 | 19 | 6.6 | 0.8 | E | 0 |
| **MAR** | 33 | 20 | 95 | 18 | 5.2 | 0.5 | ENE | 10 |
| **APR** | 37 | 25 | 85 | 25 | 5.0 | 1.1 | E | 15 |
| **MAY** | 35 | 23 | 92 | 22 | 7.7 | 0.8 | E | 35 |
| **JUNE** | 32 | 22 | 93 | 60 | 7.7 | 2.2 | W | 45 |
| **JULY** | 30 | 20 | 94 | 45 | 7.5 | 2.2 | WSW | 45 |
| **AUG** | 31 | 19 | 95 | 56 | 6.6 | 1.1 | WSW | 20 |
| **SEPT** | 33 | 19 | 95 | 40 | 6.6 | 0.8 | WSW | 5 |
| **OCT** | 29 | 18 | 96 | 65 | 6.1 | 0.5 | SW | 5 |
| **NOV** | 31 | 18 | 94 | 53 | 6.1 | 0.8 | E | 0 |
| **DEC** | 28 | 17 | 93 | 46 | 5.0 | 0.5 | NNE | 5 |

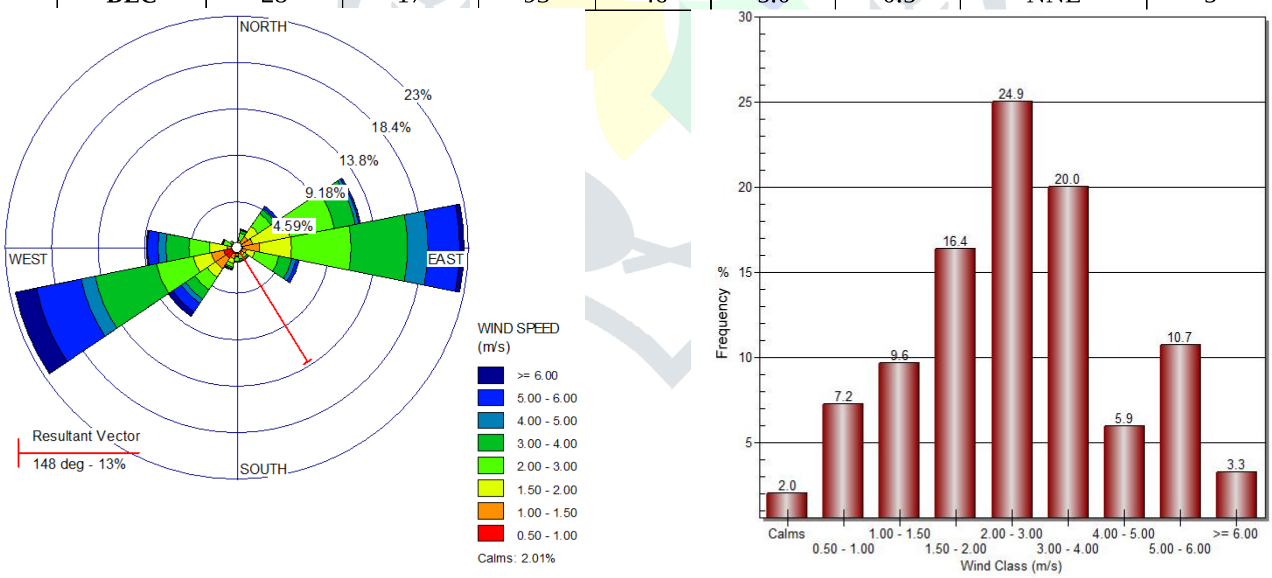


Fig. 2. Windrose diagram and frequency distribution of various wind classes over Mysuru City for the Year 2018

*Traffic Count Studies*

Traffic count studies were conducted to understand the variation of different category of vehicles over the study area. As the study area is situated far away from industrial zone, it was assumed that, the main contribution of the pollutants were from road traffic. A CCTV camera was installed for the recording of daily traffic counts. Average daily traffic variation is showed in the Fig. 3. It was observed that, during the early morning hours traffic density was very low. However, a sudden increase in traffic density was observed between 8:00 hrs to 10:00 hrs. This may be due to office and school timings as most of people are travelling for their work. A moderate traffic was observed between 11:00 hrs to 17:00 hrs. This may be due to the off-traffic hours. however, a peak was again observed after 18:00 hrs to 20:00 hrs as people were returning from office, school and colleges. It was noticed from the traffic count studies that, number of 2W vehicles were found to be maximum followed by 4W, HDV, LDV and 3W. A maximum of 2000 two-wheeler vehicles were observed at 8:00 hrs. The study conducted by Khare et al. (2012) and Sharma et al. (2013) [9,10] at Delhi was also found the peak traffic hours between 08:00 – 10:00 hrs and 18:00 – 20:00

hrs. Weekly variation of the vehicles were also calculated (Fig. 4.) and observed that, it follows the previous trend. Major HDV vehicles were observed late night and early morning period due to the city restriction. Less vehicles were observed on Sunday as it is holiday, when compared to other working day. However, moderate traffic was found on Sunday, as most of the people go for recreation purpose and outing.

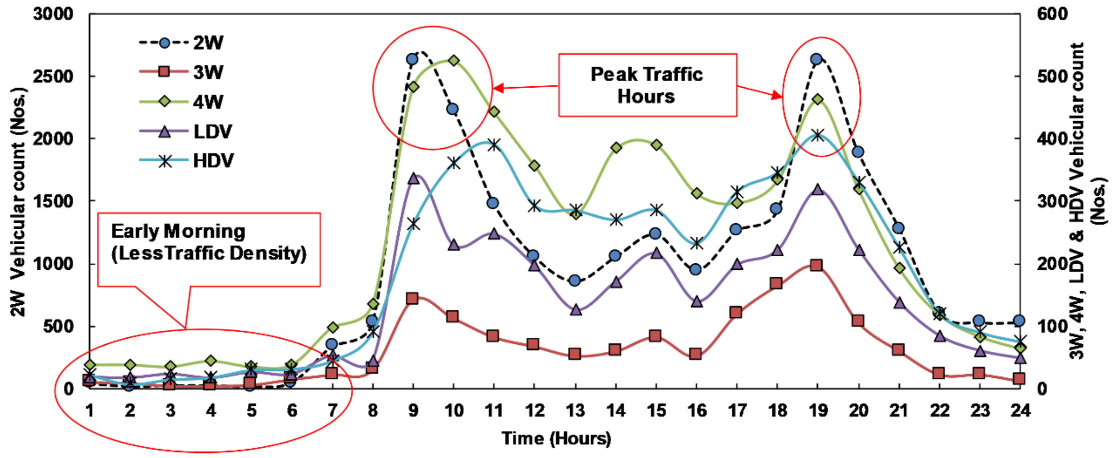


Fig. 3. Average daily variation of different category of vehicles near Hinkal Junction

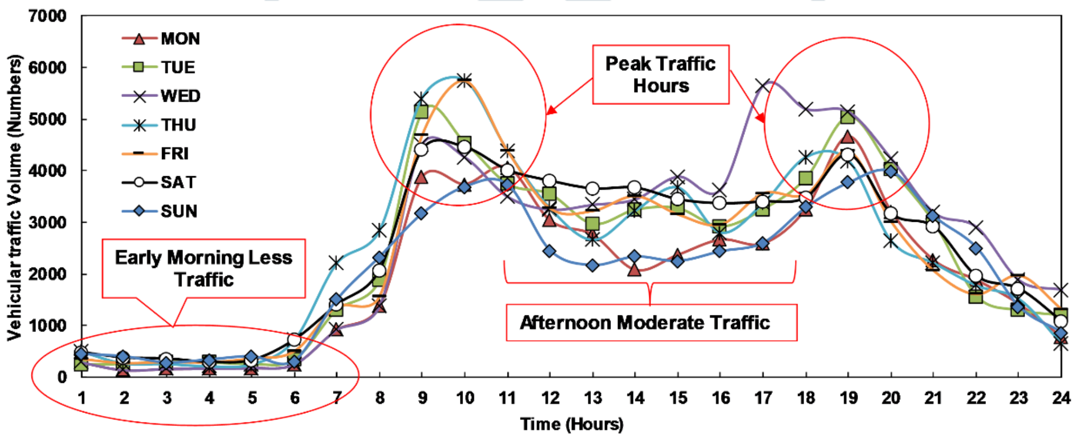


Fig. 4. Average weekly variation of different types of vehicle near Hinkal Junction

*Emission Factor Based on the Traffic Distribution*

An emission factor (EF) is a database which gives the amount and sources of air pollutants emitted into the atmosphere during in a given period of time. The EF relevant to vehicle categories such as 2W, 3W, 4W, LDV, HDV and for the pollutants CO, HC, $CO_2$, $PM_{10}$ and NOx were obtained from the Automotive Research Association of India (ARAI) and calculated for current traffic density. The hourly variation of emission factors for different types of pollutants along the highway stretch is as shown in the Fig. 5. However, it was noticed that, due to the traffic variations at different hours of the day, the amount of air pollutants emitted into the atmosphere was also varied. As Emission factor is a function of total number of vehicle and emission rate, EFs were found to be maximum during early morning (04:00 – 06:00 hrs) time and late night (22:00 – 02:00 hrs) and found to be minimum between 08:00 and 11:00 hours (morning peak hours) and, 18:00 and 20:00 hours (evening peak hours). It was observed that, as the vehicular number increases emission factors decreases. Hence, during the peak traffic hour's minimum emission factors were observed. Maximum emission factors were observed for the pollutant $CO_2$ followed by CO, HC and PM. Maximum emission factors for $CO_2$ was varying from 300 – 600 g/mi. However, emission factors for CO and HC were varying from 5 – 12 g/mi and 1 – 3 g/mi, respectively.

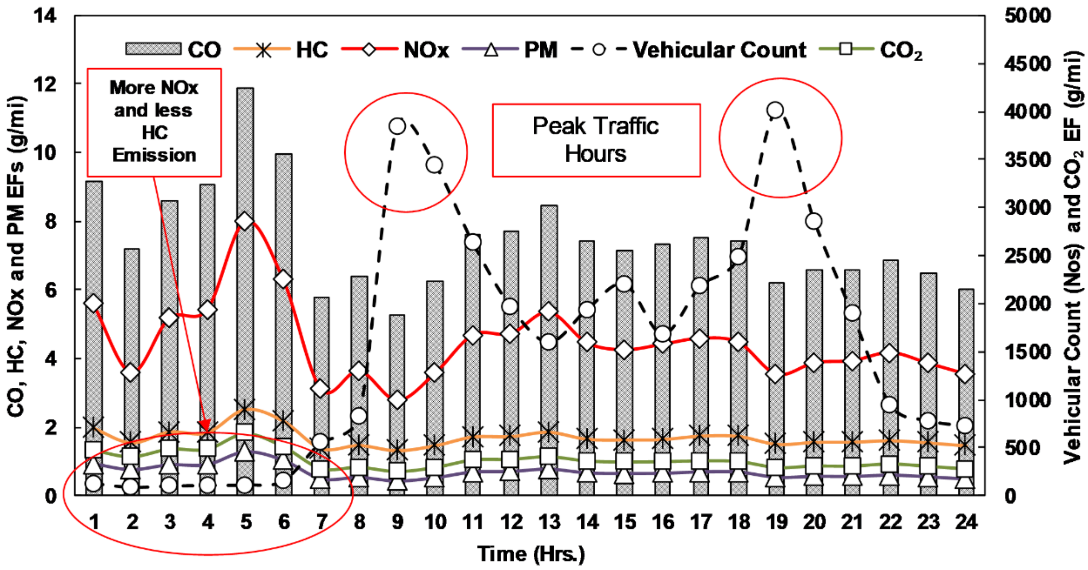


Fig. 5. Diurnal variation of Emission Factors for different category of pollutant

*Percentage Distribution of Vehicles and EFs*

An attempt has been made to understand the percentage distribution of different traffic density based on total number of vehicles counted in the study area (Fig. 6.). It was observed that, traffic distribution was mainly dominated by 2W almost ~61 %, followed by 4W (15%), HDV (12 %), followed by LDV comprising 8 % and 3W (4 %) at the study area. The reason for maximum 2W may be due to easily affordable vehicle and quickly reachable to the shorter destination even in moderate to heavy traffic densities. ARAI emission factors were used to identify the NOx, $PM_{10}$, $CO_2$ and HC emission factors from each category of vehicles (Figs. 7-8). From the Fig. 7. it was observed that, NOx was mainly contributing from HDV (74 %) followed by 2W (13 %), LDV (8 %), 3W and 4W (2-3 %). A similar observation was made for $PM_{10}$ and $CO_2$ pollutants also. $PM_{10}$ and $CO_2$ were mainly contributed from HDV (55-64 %) followed by LDV (15-17 %), 2W (6-14 %), 3W and 4W (3-11 %). However, for HC, major contributor was found to be HDV followed by 2W and LDV.

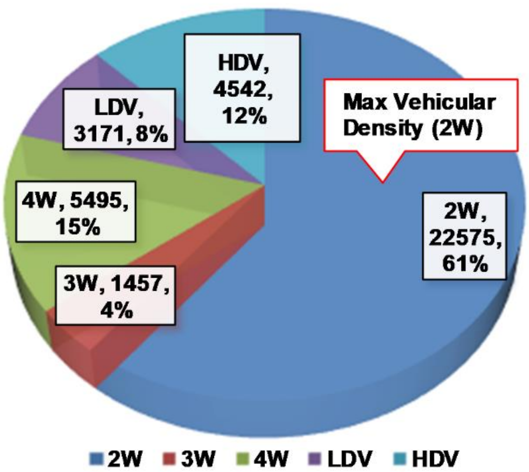


Fig. 6. Percentage contribution of traffic volume over the study area

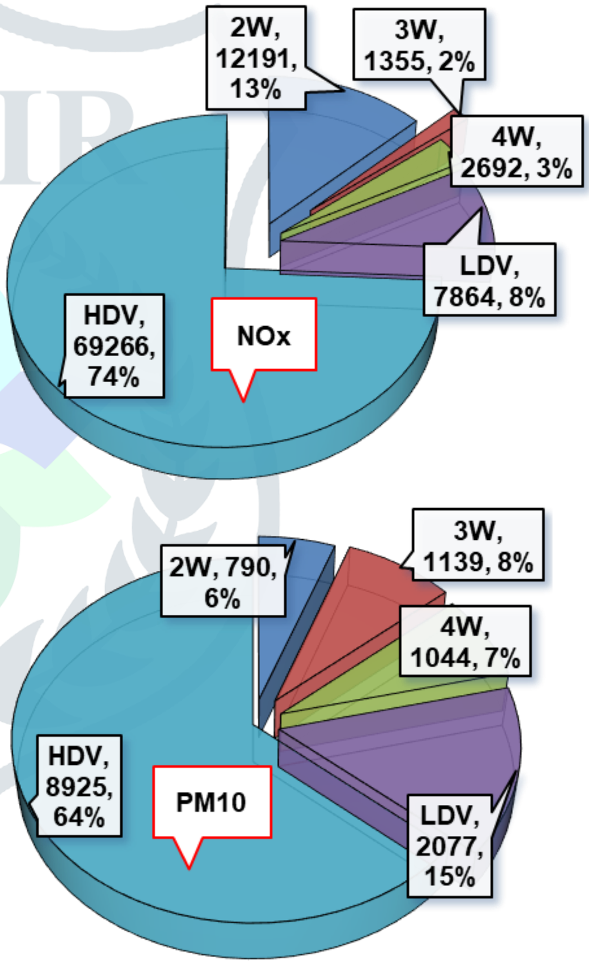


Fig. 7. Percentage contribution of NOx and $PM_{10}$ emission factors from different category of vehicles

It was clearly understood the, though the number of 2W was maximum in traffic distribution but maximum load was contributing from HDV, LDV and 4W vehicles. This may be due to the bigger sized vehicle with higher engine capacity, which need more fuel and generate more amount of pollutants. Goud et al. (2015) [11] reported that, traffic composition was dominated by 2W (42 – 43 %), followed by 4W (39 – 40 %), 3W (8 – 9 %), LCV (5 – 6 %) and HDV (4 %) at Central Silk Board intersection, Bengaluru, India. Bhanarkar et al. (2005) [12] also reported that, largest contribution of $NO_2$ (57 %) among the vehicular emissions was due to heavy-duty vehicles in Jamshedpur region, India.

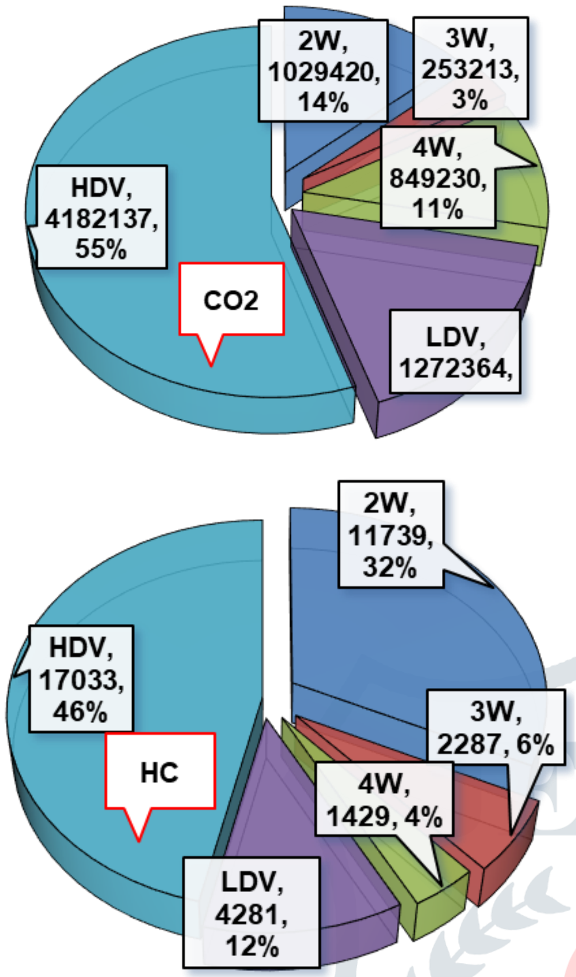


Fig. 8. Percentage contribution of $CO_2$ and HC emission factors from different category of vehicles

*Carrying Capacity Based on Ventilation Coefficient*

The ventilation coefficient (VC) is directly proportional to the carrying capacity / assimilative potential of the atmosphere and has been calculated using MMD and wind speeds over the study area for the year 2018 and represented in Fig. 9. An increase in solar insolation, as the day advances the VC also increases reaching a maximum value during afternoon hours. Further during evening hours when the incoming solar radiation ceases the VC also gradually decreases [13]. The ventilation coefficient values were very low (< 2000 $m^2/s$) during morning (01:00 – 08:00 h) and evening/night hours (23:00 – 24:00 h) indicating high pollution potential or low assimilative capacity during these periods. This implies, if pollutants are emitted in this period, atmosphere is having less potential to carry away or more load or impact over the system. However, VC was more during day time, when atmosphere is unstable. Maximum VC was observed to be 8000 $m^2/s$ at 15:00 – 16:00 hrs, implies a favorable condition for the dispersion or mixing of pollutants emitted from vehicles. Thus, it can be concluded that, the VC simply provides a broad indication of the dispersion potential in terms of low (< 2000 $m^2/s$), medium (2000 – 6000 $m^2/s$) or high (> 6000 $m^2/s$) of the atmosphere [14]. Krishna et al. (2004) [15] have reported that, maximum VC was found to be 13,924 $m^2/s$ during winter season when compared in 9781 $m^2/s$ during summer season at Visakhapatnam.

*Impact of air pollution on the surroundings*

Meteorological data were collected to understand the affect the various meteorological factor over the study area. It was observed that, wind was majorly blowing from East and West-South-West directions, which imply the pollutants from the vehicles most of the time dispersing West and East-North-East direction. As the residential area is situated at East and South direction, vehicular pollution will affect these areas (Fig. 10.). It was found that, the wind speeds were varying from 0.5 m/s to 7.7 m/s. When the wind was blowing at a speed of 7.7 m/s, implies an unstable condition, favorable for better mixing of pollutants. Due to the maximum wind speed, pollutant concentration will be less, however, the situation will be reverse when wind speed is 0.5 m/s. Due to the low wind speed pollutant will not disperse in the atmosphere and heavily concentrated near to the source. The traffic density studies showed a maximum traffic density during 08:00-10:00 hrs and 18:00-20:00 hrs, which mean during these hours the pollution will be more and remaining hours pollution will be less. As the study area is handling ~38000 vehicles per day, the load in one day over the area is very high in terms of EFs. The study of Ventilation Coefficient showed during late night and early morning VC values were less, causing more pollution potential. However, during morning period with the sunrise, atmosphere start becoming unstable and VC value reaches maximum, implies a favorable condition for mixing and dispersion of the pollutants.

## IV. Conclusions

The present study was conducted to understand the traffic flow in Hinkal area, Mysuru, Karnataka, as this place is one of the most traffic congested regions in Mysuru. A maximum and minimum temperature of 37°C and 15°C was noticed in the month of April and February, 2018, respectively. Meteorological data showed a maximum wind velocity of 7.7 m/s in the month of May and June, 2018 and a minimum of 0.5 m/s in January, March and December, 2018. Windrose plot represents a predominant wind was blowing from East to West direction and West-South-West towards East-North-East direction. The traffic density studies showed a maximum traffic density during 08:00-10:00 hrs and 18:00-20:00 hrs, however, a moderate traffic was observed between 11:00 hrs to 17:00 hrs. For the same traffic density, maximum EFs for $CO_2$ was varying from 300–600 g/mi followed by CO and HC from 5–12 g/mi and 1–3 g/mi, respectively. It was noticed that, as the vehicular number increases emission factors decreases. Traffic distribution was mainly dominated by 2W almost ~61 %, followed by 4W (15%), HDV (12 %), followed by LDV comprising 8 % and 3W (4 %) at the study area. NOx was mainly contributing from HDV (74 %) followed by 2W (13 %), LDV (8 %), 3W and 4W (2-3 %). A similar observation was made for $PM_{10}$ and $CO_2$ pollutants. The residential area is situated at East and South direction and vehicular pollution may affected the area because wind was majorly blowing from East and West-South-West directions. As the Ventilation Coefficient was found to be minimum during early morning and late-night periods, which indicates lower carrying capacity of the atmosphere, so, it is suggested to control the vehicular pollution during these periods. Pollution from vehicle is mainly due to exhaust emission, crank-case emission and evaporative emission. Catalytic converters hold great promise for the future and their wide acceptance seems to be around the corner. Catalytic converters depend on the action of a catalyst containing certain exotic chemicals to convert HC and CO emissions to their oxidized product.

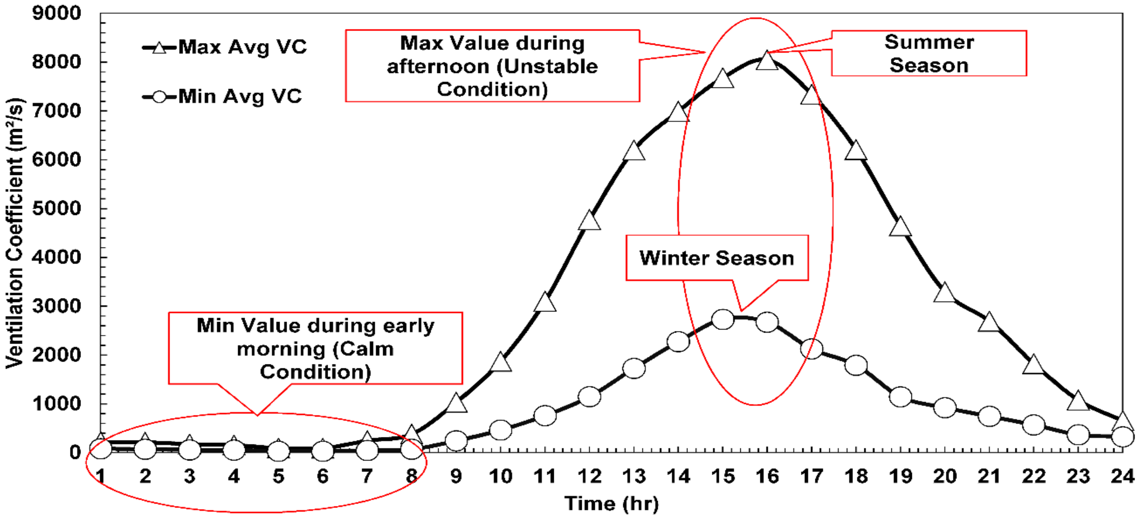


Fig. 9. Diurnal variation of maximum average and minimum average ventilation coefficient over Mysuru city for the year 2018.

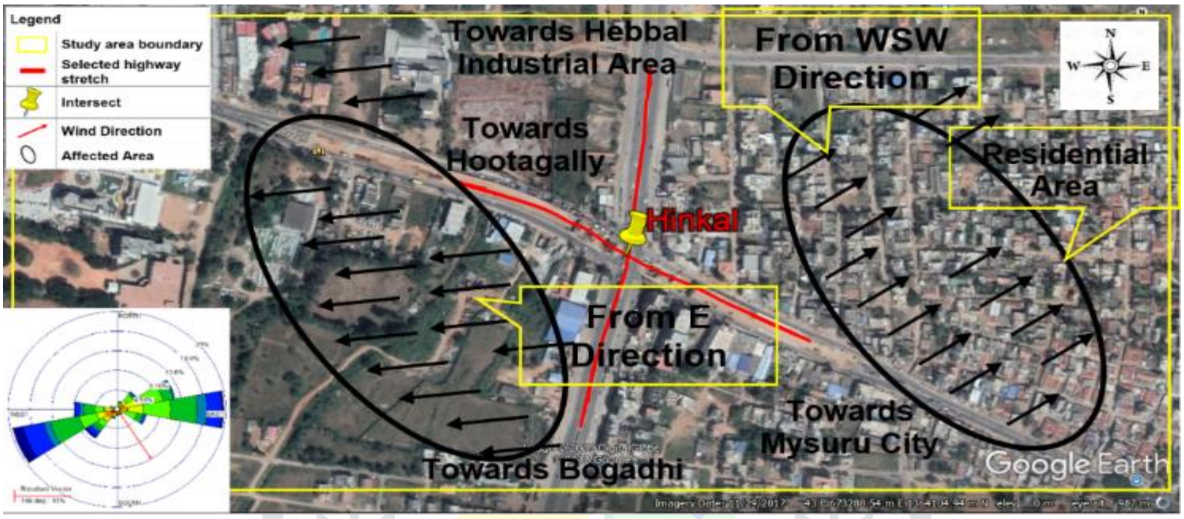


Fig. 10. Probable dispersion of air pollutants over the study area due to line sources contribution

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