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# Assimilative Capacity and Air Quality Index Studies of the Atmosphere in Hebbal Industrial Area, Mysuru

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**ABSTRACT:** Industrialization and increase in density of vehicle are being the major concerns of air pollution in urban areas. Focused on assimilative capacity of the atmosphere and determination of air quality index (AQI) of industrial areas are of more concern in the allocation of new industries in the existing industrial areas of towns and cities. Air quality monitoring studies were conducted from November, 2016 to June, 2017 at Hebbal industrial area, Mysuru, Karnataka, India. The wind rose plots during winter indicated the predominant wind was blowing from E (90°) and ENE (68°) and during summer wind was blowing from SW (225°) and WSW (248°) towards NE (45°) and ENE (68°). A maximum wind speed of 7.77 m/s was observed during monsoon season. The results of Ambient Air Quality Monitoring Studies (AAQMS) at Hebbal Industrial area showed, during winter season PM<sub>10</sub> and PM<sub>2.5</sub> concentrations were found to be 177.3 and 64.2 µg/m<sup>3</sup>, respectively at Location 1, which was more than the National Ambient Air Quality Standard (NAAQS) of 100 and 60 µg/m<sup>3</sup>, respectively. NO<sub>x</sub> and SO<sub>2</sub> concentrations at Hebbal industrial area, were found to be within NAAQS of 80 µg/m<sup>3</sup>. The average ventilation coefficient (VC) observed to be highest during summer season (7631 m<sup>2</sup>/s at 16:00 h) followed by winter (5009 m<sup>2</sup>/s at 15:00 h) and lowest during monsoon season (4114 m<sup>2</sup>/s at 16:00 h). Assimilative capacity for PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> during summer and monsoon seasons were noticed to be within the permissible limits. During winter season Air Quality Index (AQI) was found to be 'moderate' at location 1 and 2, due to high pollution load, implying a 'poor' air quality during winter season. However, during summer AQI was found to be 'satisfactory' at all the locations and in monsoon season AQI at location 2 and 3 was found to be 'good' due to the occurrence of precipitation and unstable atmospheric conditions.

**KEYWORDS:** Diurnal variation, Assimilative capacity, Ventilation coefficient, Pollution potential, Air Quality Index.

### I. INTRODUCTION

Rapid industrial development coupled with emission from transport sector has fuelled the process of ambient air pollution, particularly in mega cities and urban areas [1,2,3,16]. Combustion of fossil fuel is one of the principal sources of emission of greenhouse gases and aerosols to the atmosphere [4]. Air pollution has severely affected lives of people and caused greater damage to the ecosystems and society [49,50]. Apart from air quality deterioration, atmospheric emissions lead to phenomena such as, acidification and eutrophication [17] and occurrence of large-scale pollution haze [25] leading to disturbances in the climate and water cycles [36]. Nitrogen dioxide (NO<sub>2</sub>) absorbs visible solar radiation and contributes to reduced atmospheric visibility. The major sources of NO<sub>2</sub> into the atmosphere are from specific non-combustion industrial processes such as, manufacturing of nitric acid, use of explosives and welding. However, these days large amount of NO<sub>2</sub> is contributed from vehicular emissions [4,5,20,35]. Inhalation of air

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Vol. 6, Issue 10, October 2017

pollutants such as, ozone, nitrogen dioxide and phosgene, which are poorly soluble in water, can induce lung vascular leakage and inflammation [10,22]. The major source of sulfur dioxide (SO<sub>2</sub>) into the atmosphere is from combustion of fossil fuels in the power plants and other industrial facilities [5,35]. Inhalation of SO<sub>2</sub>, chlorine and ammonia induce undesirable changes in the nasopharyngeal region and upper airways in humans due to their high water solubility [21,26,28,46]. Further, sources of particulate matter (PM) include emissions from power plants, large industries, vehicular emission, domestic fuel burning [39], which causes adverse effects on human health such as, lung disease, increased cancer risk, and increased risk of cell mutations [6,7,9,18,19,27].

Meteorological parameter is one of the important factors that control the air pollution in terms of dilution, mixing and dispersion of air pollutants [12,14,23,30]. The assimilative capacity of air environment is defined as the maximum amount of pollution load that can be discharged without violating the best designated use of the air resource in the planning region [12]. Singh et al. (1990) have analysed the dispersion of SO<sub>2</sub>, suspended particulate matter (SPM) and NO<sub>x</sub> pollutants over Delhi city, India [41]. Assimilative capacity of the atmosphere was also studied by Nandankar (1999) for Lucknow city, India [31]. Earlier various researchers have calculated ventilation coefficient and pollution load to understand the assimilative potential of the atmosphere such as, Padmanabhamurty and Mandal, 1979 (Delhi) [33]; Manju et al., 2002 (Manali) [30]; Goyal et al., 2003 (Delhi) [13]; Krishna et al., 2004 (Visakhapatnam) [23]; Goyal et al., 2005 (Gangtok) [11]; Goyal and Rao, 2007 (Kochi) [14]; Thepanondh and Jitbantoung, 2014 (Dawai) [44] and Thawonkaew et al., 2016 (Thailand) [43]. Rao et al. (2015) found maximum VC during pre-monsoon followed by monsoon, post-monsoon and winter season in Visakhapatnam [37]. On the other hand, Sarella and Khambete (2015) showed moderately polluted air quality index for Vapi city, Gujarat, India [38]. Chaurasia et al. (2013) have reported that, AQI was found to be 'moderate' in terms of PM<sub>10</sub> and PM<sub>2.5</sub> concentration at selected receptor points in Bhopal city [8]. Kumar and Kriti (2016) have stated, AQI of Jaipur City, Rajasthan, India was found to be 'poor' in terms of PM<sub>10</sub> concentration [24]. The analysis of air quality in Delhi city, India, showed a gradual deterioration in terms AQI values from 2005 onwards [29]. Thilagaraj et al. (2014) have reported, Kilpauk is being the most polluted place in Chennai city which is based on AQI values [45]. Mysuru is experiencing a deteriorated ambient air quality due to industrialization and vehicular fleet. Based on the vehicle growth during the last few years, it is observed that, the vehicle growth in Mysore city is about 8 to 9 % p.a. and 2-wheelers constitute more than 75 % of total vehicular population. The total number of vehicles which was about 6000 in 1970 increased to 1.45 lakhs in 1996, 3.55 lakhs in 2005 and the current vehicle population is 6.5 lakhs (2014). In most of the air pollutant dispersion studies very few researchers have worked on the identification of Assimilative Capacity and Air Quality Index (AQI) of Mysuru city. Hence, the aim of the present study is to determine the Ambient Air Quality (AAQ) and Air Quality Index (AQI) of Hebbal industrial area and also to identify the assimilative capacity based on Ventilation Coefficient (VC) and pollution potential.

## II. STUDY AREA

The cleanest city of the South-Western state of Karnataka i.e., Mysuru is geographically located at 12° 18' N and 76° 39' E. Major industrial areas are located in North-Western part of Mysuru, within radius of 7 km from the city centre and the industrial area is well connected by State Highway (SH) and broad ring roads [34]. The Hebbal industrial area is located North-West part of the study area. Three monitoring stations along the highway (Figure 1) with 1 km interval were selected for Ambient Air Quality Monitoring (AAQM) with 6 receptor points these include: Seshadripuram College (R1), Weigh Bridge (R2), V-LEAD Institute (R3), Prema Fuel Station (R4), Dexter Logistics (R5) and JSS Urban Haat (R6).

## III. MATERIALS AND METHODS

### Meteorological data

Meteorological parameters which influence the dispersion of air pollutants include: wind speed, wind direction, temperature, precipitation, relative humidity, mean mixing depth (MMD). In the present study, daily and hourly meteorological data were collected from November, 2016 to June, 2017, considering winter, summer and monsoon

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Vol. 6, Issue 10, October 2017

seasons from the website [www.wunderground.com](http://www.wunderground.com) [51], which were used for plotting diurnal and seasonal variation of meteorological parameters.



Fig. 1. Study area showing the AAQM locations along the highway passing through the industrial area of Mysuru.

## Ambient air quality monitoring (AAQM)

Ambient Air Quality (AAQ) was monitored from November, 2016 to June, 2017, considering winter, summer and monsoon seasons at three identified locations with six receptor points along the highway passing through industrial area of Mysuru city for PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> air pollutants. The monitored air pollutant concentrations were used to calculate the assimilative capacity in terms of pollution potential and as well as air quality index of the study area.

## Assimilative capacity of the atmosphere

Assimilative capacity refers to the ability of the environment to carry the pollutants without adverse effects on the environment or on users of its resources. Manju et al. (2002) have stated that, assimilative capacity of the atmosphere determines the maximum pollutant load that can be discharged into the atmosphere without violating the best-designed use of air resources in the planning region [30]. The assimilative capacity of the atmosphere can be determined using two approaches. The first approach is based on ventilation coefficient, which can be calculated by meteorological parameters and the second approach is based on pollution potential due to the presence of various air pollution sources in the study area. The pollution potential indicates the capacity of the atmosphere to dilute the pollutants and the resulting effects on quality of air [13].

## Assimilative capacity based on ventilation coefficient

In the present study assimilative capacity of the environment was calculated by ventilation coefficient approach, using eqn. (1).

$$\text{Ventilation coefficient (m}^2/\text{s)} = \text{Wind speed (m/s)} \times \text{MMD (m)} \quad (1)$$

The United State National Meteorological Centre and Atmospheric Environment Services, Canada, has classified that, the assimilative capacity of the atmosphere will be considered as 'low' if the ventilation coefficient is < 6000 m<sup>2</sup>/s (during afternoon), mean wind speeds < 4 m/s and mixing depths < 500 m (during morning) [15,42].

## Assimilative capacity based on pollution potential

The second approach is based on the pollution potential in terms of concentration of pollutants measured during monitoring days. Assimilative capacity was determined by considering the difference between the permissible and the existing pollutant concentration levels, for the study region, using eqn. (2).

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 10, October 2017

Available assimilation potential = Permissible standard – Pollutant concentration (2)

### Air Quality Index (AQI)

The AQI is an index for reporting daily air quality. It indicates about air quality of any location and associated health effects due to the air quality. The AQI focuses on health effects that may experience within a few hours or days after breathing polluted air. In the present study AQI was calculated using eqn. (3).

$$I_P = \left[ \frac{I_{HI} - I_{LO}}{B_{PHI} - B_{PLO}} * (C_P - B_{PLO}) \right] + I_{LO} \quad (3)$$

Where,  $I_P$  is AQI for pollutant “P”,  $C_P$  is the actual ambient concentration of pollutant “P”,  $B_{PHI}$  is the upper end breakpoint concentration that is greater than or equal to  $C_P$ ,  $B_{PLO}$  is the lower end breakpoint concentration that is less than or equal to  $C_P$ ,  $I_{LO}$  is the sub index or AQI value corresponding to  $B_{PLO}$ ,  $I_{HI}$  is the sub index or AQI value corresponding to  $B_{PHI}$ .

## IV. RESULTS AND DISCUSSION

### Meteorological data

Dispersion of air pollutants depend upon various meteorological factors, hence, the hourly meteorological data were collected and used to plot monthly and seasonal variation of wind velocity, temperature, relative humidity.

### Seasonal variation of temperature and relative humidity

Ambient temperature and relative humidity data were collected for winter, summer and monsoon seasons for the study area. Temperature was found to be minimum at 03:00 to 07:00 h (Figure 2) and it gradually increased and reached peak at 14:00 to 16:00 h and there onwords decreased in all the seasons. A maximum temperature of 37°C was observed during summer and a minimum temperature of 15°C was noticed during winter season. Average temperature was varying from 24°C to 28°C during the entire study period. Further, maximum relative humidity (RH) was found to be 96% during pre-monsoon and a minimum of 19% was noticed during winter season. RH was maximum at 02:00 to 07:00 h and it gradually decreased and reached the minimum at 14:00 to 17:00 h and then started increasing (Figure 3). However, during monsoon not much variation of temperature and RH were observed. It was also observed that temperature and RH were inversely proportional to each other.

### Seasonal variation of Mean Mixing Depth (MMD) and stability class of atmosphere

The variation of MMD was mainly due to variations in ambient temperature as well as wind speed. However, from the diurnal variation of MMD (Figure 4) it was found that, MMD was very low i.e., less than 100 m during morning / late night hours from 01:00 h to 07:00 h. Highest MMD value was observed between 13:00 h to 16:00 h, which found to be 1808 m, 1417 m and 1137 m, during summer, winter and monsoon seasons, respectively. The lower values of mixing height during late night and early morning hours could be due to the occurrence of ground based inversions that hamper dispersion [33]. Atmospheric stability (Pasquill classification, A – F / 1-6) are compiled by using wind speed, cloud cover and solar insolation following Turner’s (1969) table [47]. Stability class 5 (E) and 6 (F) prevailed from 22:00 h to 06:00 h during winter and monsoon seasons (Figure 5). Atmospheric stability gradually changed to unstable condition (1-2) from 06:00 h on-wards due to sunrise which increases the atmospheric temperature. The air mass reached the highly unstable class at midday when wind speed was maximum indicating high MMD and better mixing of pollutants during daytime. However, during night time atmosphere became stable which indicated a poor mixing during late night time.

### Seasonal variation of wind speeds and wind directions

Major meteorological factors which govern the dispersion of air pollutants are wind speed and its direction. A plot of wind speed against time for winter, summer and monsoon seasons were made shown in Figure 6. Wind speed

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Vol. 6, Issue 10, October 2017

was found to be minimum at 01:00 to 07:00 h and it gradually increased due to sunrise and reached peak values at 14:00 to 17:00 h and there on-wards started decreasing during winter and summer seasons. However, during monsoon season, wind velocities were found to be maximum, indicating dispersion of pollutants. A maximum wind speed of 7.77 m/s was noticed during monsoon season and a minimum wind speed of 0.55 m/s was noticed during winter season.

The wind rose plots for winter season (Figure 7) showed the predominant wind was blowing from E (90°) and ENE (68°) directions. The average wind velocity was observed 2–3 m/s during December, 2016. However, during January and February average wind speeds were found to be 3–4 m/s. The resultant vector of wind directions for winter season to summer season showed, wind direction was changing from E direction to WSW direction. However, from the wind rose plots of summer season (Figure 7) it was observed that, predominant wind was blowing from SW (225°) and WSW (248°) towards NE (45°) and ENE (68°) directions, respectively. The average wind speed of 1.5-3 m/s was observed during March and 3–4 m/s was observed during April. The resultant vector of wind directions for summer season to monsoon season (Figure 7) showed wind direction was changing from SW direction to WSW direction.

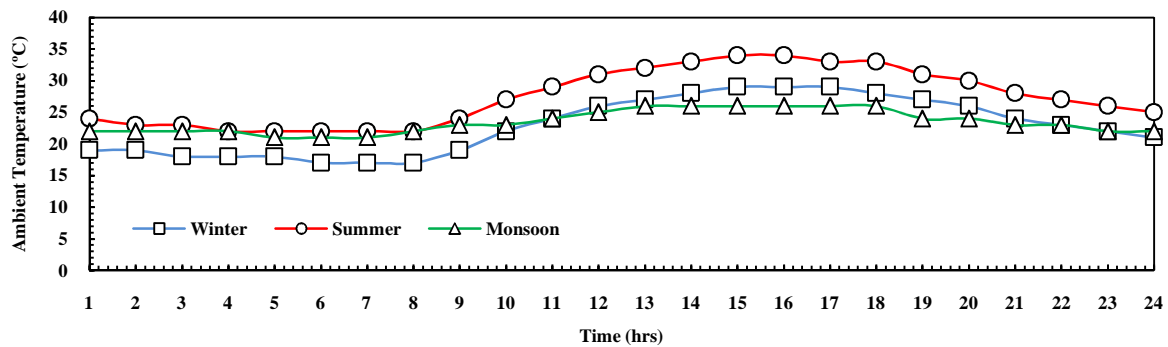


Fig. 2. Diurnal variation of ambient temperature during winter, summer and monsoon seasons over Mysuru city.

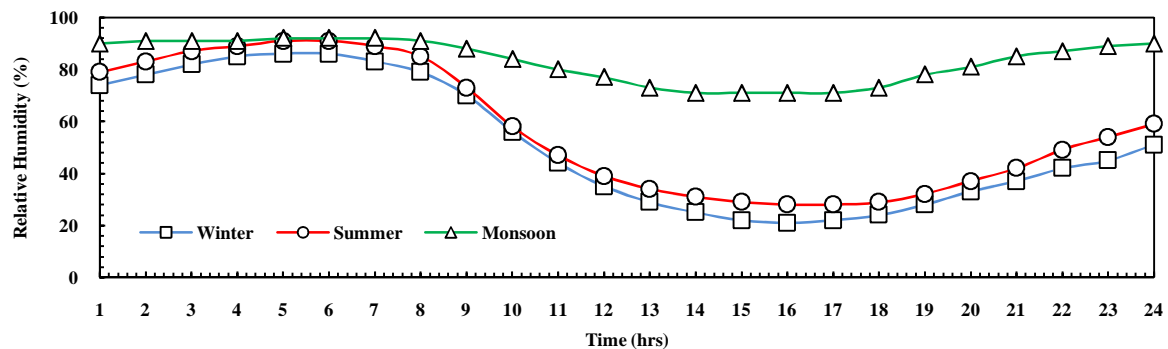


Fig. 3. Diurnal variation of relative humidity during winter, summer and monsoon seasons over Mysuru city.

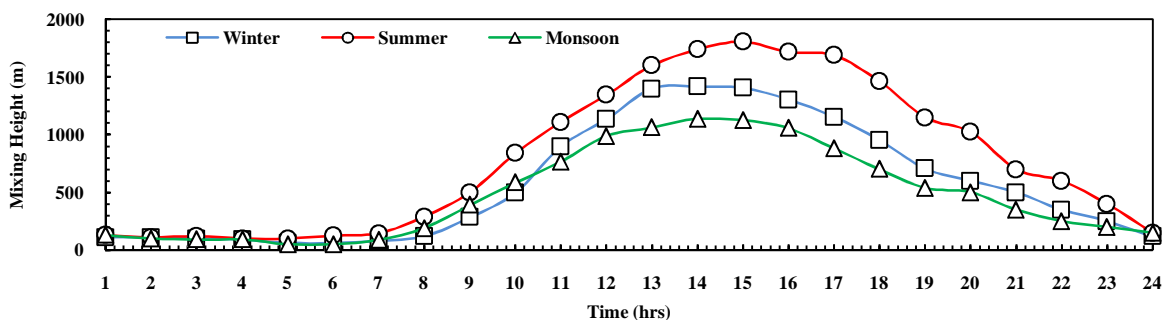


Fig. 4. Diurnal variation of mixing heights during winter, summer and monsoon seasons over Mysuru city.

# International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 10, October 2017

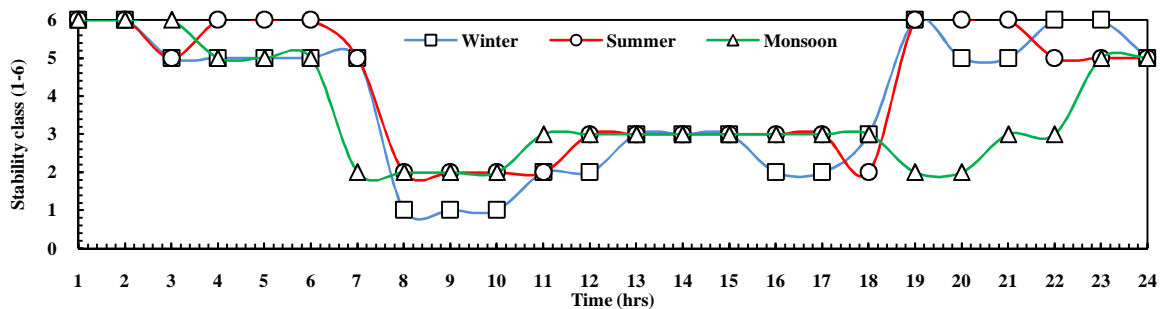


Fig. 5. Diurnal variation of atmospheric stability class during winter, summer and monsoon seasons over Mysuru city.

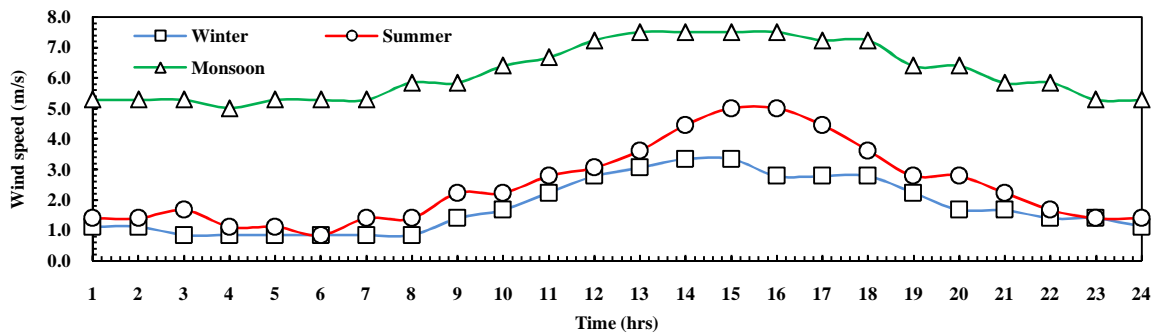


Fig. 6. Diurnal variation of wind speeds during winter, summer and monsoon seasons over Mysuru city.

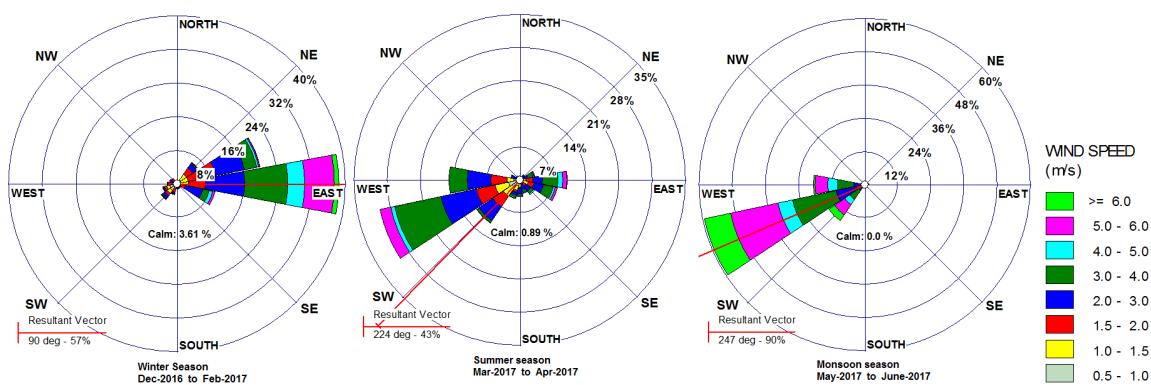


Fig. 7. Windrose plots for winter, summer and monsoon season over Mysuru city.

## Ambient air quality monitoring (AAQM)

The AAQM was conducted for 8 hours from 10.00 am to 06.00 pm for the pollutants such as,  $PM_{10}$ ,  $PM_{2.5}$ ,  $NO_x$  and  $SO_2$ . The observed pollutant concentration during winter, summer and monsoon seasons are presented in Table 1.  $NO_x$  and  $SO_2$  concentrations in all the receptor points monitored were found to be within the permissible limits of National Ambient Air Quality Standards (NAAQS) [32] of  $80 \mu g/m^3$ . However,  $PM_{10}$  concentration at location 1 was found to be exceeding the NAAQS [32] of  $100 \mu g/m^3$  during winter season. Further,  $PM_{2.5}$  concentration was also found to be within NAAQS [32] of  $60 \mu g/m^3$  at all the receptor points except during winter season at location 1. The Ambient Air Quality (AAQ) study conducted by Prakash et al. (2015 and 2016) in the industrial area of Mysuru

## International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 10, October 2017

have also observed similar results for PM<sub>10</sub> and PM<sub>2.5</sub> of exceeded pollutant concentration during winter season due to calm atmospheric condition [34,35].

Table 1: Results of Ambient Air Quality Monitored data during winter, summer and monsoon season.

Monitoring stations		Parameters Analyzed along with standards ( $\mu\text{g}/\text{m}^3$ )											
		Winter season				Summer season				Monsoon season			
		PM <sub>10</sub> (100)	PM <sub>2.5</sub> (60)	NO <sub>x</sub> (80)	SO <sub>2</sub> (80)	PM <sub>10</sub> (100)	PM <sub>2.5</sub> (60)	NO <sub>x</sub> (80)	SO <sub>2</sub> (80)	PM <sub>10</sub> (100)	PM <sub>2.5</sub> (60)	NO <sub>x</sub> (80)	SO <sub>2</sub> (80)
L1	(R-1)	177.3	56.5	28.5	1.9	68	34.3	31.4	1.6	52	17	19.8	0.6
	(R-2)	146.6	64.2	21	1.4	79	24.7	21.3	1.4	54	15	12.3	0.5
L2	(R-3)	98.1	24.2	23.7	1.2	50	21	25.5	1.45	39	9.2	12.7	0.2
	(R-4)	139.3	26.9	26.3	2.6	82	32	31.1	2.3	43	12	20.1	0.7
L3	(R-5)	65.1	23.1	17.9	1.0	52	19	19.5	1.0	42	10	12.5	0.3
	(R-6)	76.2	19	22.2	1.7	60	30	22.3	1.2	35	11.5	17.4	0.3

### Carrying capacity based on ventilation coefficient (VC)

The ventilation coefficient (VC) is directly proportional to the carrying capacity / assimilative potential of the atmosphere and had been calculated using MMD and wind speeds (Eqn. 1) during winter, summer and monsoon seasons. The hourly computed VC showed a similar diurnal trend in all the three seasons. The United State National Meteorological Centre has classified that, the assimilative capacity of the atmosphere will be considered as 'low' if the ventilation coefficient is  $< 6000 \text{ m}^2/\text{s}$ , mean wind speeds  $< 4 \text{ m/s}$  and mixing depths  $< 500 \text{ m}$  [15,42]. In the present investigation ventilation coefficient was computed and found to be very low ( $< 2000 \text{ m}^2/\text{s}$ ) during early morning (01:00 – 09:00 h) and evening / late night hours (20:00 – 24:00 h), which indicated a high pollution potential or low assimilative capacity during these periods (Figures 8-10). During winter season (Figure 8), VC was found to be maximum of  $9447 \text{ m}^2/\text{s}$  (at 14:00 h). However, during low wind period, VC was found to be  $< 6000 \text{ m}^2/\text{s}$  throughout the day. Further, during summer season (Figure 9) maximum VC was found to be  $12053 \text{ m}^2/\text{s}$ , indicating a better dispersion capacity of the atmosphere. Maximum VC during monsoon season (Figure 10) was found to be  $8132 \text{ m}^2/\text{s}$ . The average ventilation coefficient (Figures 8-10) was found to be highest in summer season ( $7631 \text{ m}^2/\text{s}$  at 16:00 h) followed by winter ( $5009 \text{ m}^2/\text{s}$  at 15:00 h) and lowest in monsoon season ( $4114 \text{ m}^2/\text{s}$  at 16:00 h). This indicates low pollution potential or high assimilative capacity in summer season as compared to winter and monsoon seasons. Afternoon VCs were found to be higher ( $> 5500 \text{ m}^2/\text{s}$ ) during winter, summer and monsoon seasons, but only for a couple of hours (14:00 – 17:00 h), implying low pollution potential and better assimilative capacity of the atmosphere. Thus, it can be concluded that, the VC simply provides a broad indication of the dispersion potential in terms of low ( $< 2000 \text{ m}^2/\text{s}$ ), medium ( $2000 - 6000 \text{ m}^2/\text{s}$ ) or high ( $> 6000 \text{ m}^2/\text{s}$ ) of the atmosphere. But it does not give any idea about the amount of emission loads that can be assimilated in the given airshed of the region. Viswanadham and Kumar have stated that, with the increase in solar radiation (as the day advances) VC also increases and reached a maximum value during afternoon hours [48]. However, Goyal and Rao (2007) at Kochi region found that, maximum VC was estimated as  $7920 \text{ m}^2/\text{s}$  (at 15:00 h) in summer followed by  $6192 \text{ m}^2/\text{s}$  (at 16:00 h) in winter,  $3076 \text{ m}^2/\text{s}$  (at 14:00 h) in the monsoon and  $4645 \text{ m}^2/\text{s}$  (at 16:00 h) in post-monsoon season [14].

### Carrying capacity based on emission loads

In the present study carrying capacity/assimilative capacity was determined by considering the difference between permissible and existing pollutant concentration levels (Eqn. 2). Existing pollutant concentration levels may be monitored in ambient air or can be predicted using an appropriate air quality model for the existing sources that contribute to air pollution. In the present study, monitored pollutant concentration was considered for the calculation of pollution potential and the NAAQS was considered as ceiling limit for ambient air quality. The calculated assimilative capacity at location 1, 2 and 3 during winter, summer and monsoon seasons is shown in Table 2. It was observed that, during winter season PM<sub>10</sub> concentration was exceeding 90 % of guideline values at location 1 and 2, which implies a negative assimilative potential of the study area. This may be due to low wind speeds and calm atmospheric conditions

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Vol. 6, Issue 10, October 2017

observed during the sampling time in winter season. However,  $PM_{2.5}$  was found to be exceeding limiting value of  $60 \mu\text{g}/\text{m}^3$  during winter season at location 1. Further, pollutants such as  $NO_x$  and  $SO_2$  were found to be within 90 % of guideline values at all the locations during winter season. On the other hand,  $SO_2$  concentrations were found to be lowest because of low emission rate of  $SO_2$  from the industries as well as from vehicles. Hence, maximum assimilative capacity of more than  $70 \mu\text{g}/\text{m}^3$  was found for  $SO_2$ . Assimilative capacity studies during summer season (Table 2) reflected all pollutants were within 90 % of guideline values at all the locations. The assimilative capacity of  $PM_{10}$  was found to be poor at Location 1 and 2 due to fugitive emissions during summer season.

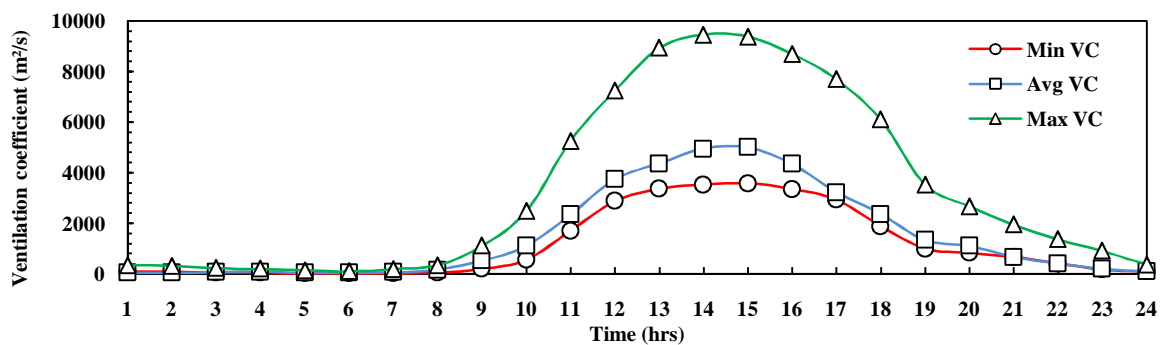


Fig. 8. Diurnal variation of minimum, average and maximum ventilation coefficient during winter season over Mysuru city.

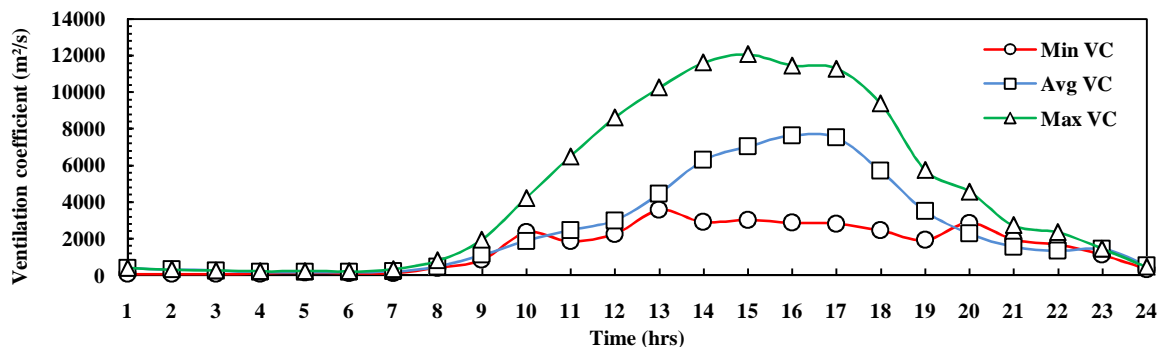


Fig. 9. Diurnal variation of minimum, average and maximum ventilation coefficient during summer season over Mysuru city.

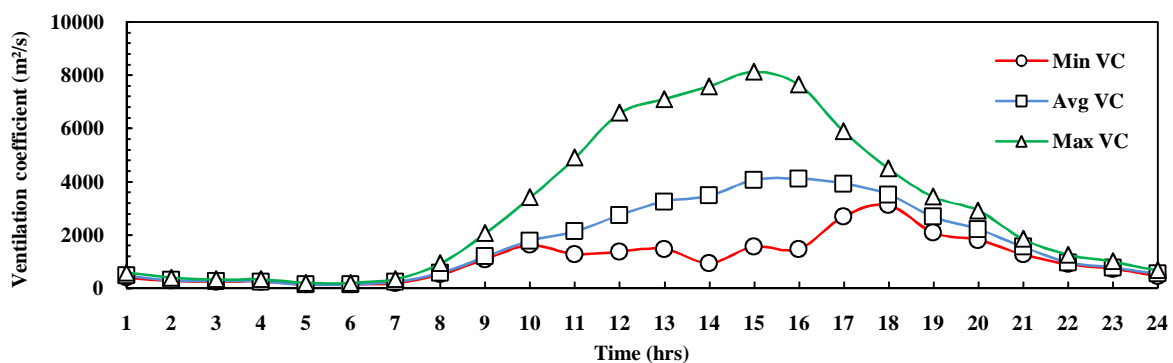


Fig. 10. Diurnal variation of minimum, average and maximum ventilation coefficient during monsoon season over Mysuru city.



## International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 10, October 2017

Table 2: Assimilative capacity of the atmosphere during winter, summer and monsoon seasons.

Locations	Pollutants	Ambient Air Quality Standards ( $\mu\text{g}/\text{m}^3$ )	90 % of guideline values (Safety Factor = 10%) ( $\mu\text{g}/\text{m}^3$ )	Maximum concentration of measured data ( $\mu\text{g}/\text{m}^3$ )	Assimilative capacity ( $\mu\text{g}/\text{m}^3$ )
<b>Winter Season</b>					
Location 1	PM <sub>10</sub> Avg. 24 hr	100	90	161.95	- 71.95
	PM <sub>2.5</sub> Avg. 24 hr	60	54	60.35	- 6.35
	NO <sub>x</sub> Avg. 24 hr	80	72	24.75	47.25
	SO <sub>2</sub> Avg. 24 hr	80	72	1.65	70.35
Location 2	PM <sub>10</sub> Avg. 24 hr	100	90	118.7	- 28.7
	PM <sub>2.5</sub> Avg. 24 hr	60	54	25.55	28.45
	NO <sub>x</sub> Avg. 24 hr	80	72	25	47
	SO <sub>2</sub> Avg. 24 hr	80	72	1.9	70.1
Location 3	PM <sub>10</sub> Avg. 24 hr	100	90	70.65	19.35
	PM <sub>2.5</sub> Avg. 24 hr	60	54	21.05	32.95
	NO <sub>x</sub> Avg. 24 hr	80	72	20.05	51.95
	SO <sub>2</sub> Avg. 24 hr	80	72	1.35	70.65
<b>Summer Season</b>					
Location 1	PM <sub>10</sub> Avg. 24 hr	100	90	73.5	16.5
	PM <sub>2.5</sub> Avg. 24 hr	60	54	29.5	24.5
	NO <sub>x</sub> Avg. 24 hr	80	72	26.35	45.65
	SO <sub>2</sub> Avg. 24 hr	80	72	1.5	70.5
Location 2	PM <sub>10</sub> Avg. 24 hr	100	90	66	24
	PM <sub>2.5</sub> Avg. 24 hr	60	54	26.5	27.5
	NO <sub>x</sub> Avg. 24 hr	80	72	28.3	43.7
	SO <sub>2</sub> Avg. 24 hr	80	72	1.875	70.125
Location 3	PM <sub>10</sub> Avg. 24 hr	100	90	56	34
	PM <sub>2.5</sub> Avg. 24 hr	60	54	24.5	29.5
	NO <sub>x</sub> Avg. 24 hr	80	72	20.9	51.1
	SO <sub>2</sub> Avg. 24 hr	80	72	1.1	70.9
<b>Monsoon Season</b>					
Location 1	PM <sub>10</sub> Avg. 24 hr	100	90	53	37
	PM <sub>2.5</sub> Avg. 24 hr	60	54	16	38
	NO <sub>x</sub> Avg. 24 hr	80	72	16.05	55.95
	SO <sub>2</sub> Avg. 24 hr	80	72	0.55	71.45
Location 2	PM <sub>10</sub> Avg. 24 hr	100	90	41	49
	PM <sub>2.5</sub> Avg. 24 hr	60	54	10.6	43.4
	NO <sub>x</sub> Avg. 24 hr	80	72	16.4	55.6
	SO <sub>2</sub> Avg. 24 hr	80	72	0.45	71.55
Location 3	PM <sub>10</sub> Avg. 24 hr	100	90	38.5	51.5
	PM <sub>2.5</sub> Avg. 24 hr	60	54	10.75	43.25
	NO <sub>x</sub> Avg. 24 hr	80	72	14.95	57.05
	SO <sub>2</sub> Avg. 24 hr	80	72	0.3	71.7

NO<sub>x</sub> concentration was found to be more in summer compared to winter and monsoon. This may be due to increase in fleet movement of vehicles in summer holidays. This could be also due to the photochemical reaction within the atmosphere which help to produce more NO<sub>x</sub> during summer season. Assimilative capacity studies during monsoon season (Table 2) showed, all pollutants were within 90 % of guideline values at all the locations. Pollutant concentrations were found to be minimum during monsoon season compared to winter and summer seasons. This may be due to the precipitation which scavenged air pollutants from atmosphere to the ground level. Hence, maximum assimilative capacity was found to be during monsoon season. Singh and Perwez (2015) [40] have reported

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Vol. 6, Issue 10, October 2017

PM<sub>10</sub> concentration at all the selected receptors in iron ore mining region of Goa were observed far below the permissible limit of 60 µg/m<sup>3</sup>. However, Goyal and Rao (2007) [14] reported highest SO<sub>2</sub> concentrations were observed in the industrial area of Kochi, India, followed by commercial and residential areas, reflecting a lowest assimilative capacity in the industrial area.

### Air Quality Index (AQI)

National Air Quality Index (AQI) transforms complex air quality data of eight pollutants into a single number (index value), nomenclature and colour. In the present study AQI for different seasons at Hebbal industrial area were determined are presented in Table 3. During winter season AQI was found to be ‘Moderate’ (141) at location 1. ‘Moderate’ AQI may cause breathing discomfort to the people with lung, heart disease, children and older adults. Unusually sensitive people should consider reducing prolonged or heavy exertion. However, during summer season AQI was found to be ‘Satisfactory’ at all the locations (74 at location 1; 66 at location 2 and 56 at location 3). ‘Satisfactory’ AQI may cause minor breathing discomfort to sensitive people. Further, during monsoon season at location 2 and 3, AQI was found to be ‘good’, which implies minimal impact to human health and a good air quality. The reason for ‘good’ AQI may be due to precipitation, which scavenged all the pollutants to the ground level. Chaurasia et al. (2013), Maji et al. (2015) and Kumar and Kriti (2016) have also reported “moderate to poor” AQI in terms of PM<sub>10</sub> and PM<sub>2.5</sub> concentrations in Bhopal, Delhi and Jaipur City, respectively [8,24,29].

Table 3: AQI for different seasons at Hebbal Industrial area

Location1	Winter		Summer		Monsoon	
Pollutant	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI
PM <sub>10</sub>	161	141 (Moderate)	73.5	74 (Satisfactory)	53	53 (Satisfactory)
PM <sub>2.5</sub>	60		29.5		16	
SO <sub>2</sub>	1.65		1.5		0.55	
NO <sub>x</sub>	24.7		26.35		16.05	
Location 2	Winter		Summer		Monsoon	
Pollutant	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI
PM <sub>10</sub>	118	112 (Moderate)	66	66 (Satisfactory)	41	41 (Good)
PM <sub>2.5</sub>	25.5		26.5		10	
SO <sub>2</sub>	1.9		1.9		0.5	
NO <sub>x</sub>	25		28.3		16.4	
Location 3	Winter		Summer		Monsoon	
Pollutant	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI	Conc. (µg/m <sup>3</sup> )	AQI
PM <sub>10</sub>	70.65	71 (Satisfactory)	56	56 (Satisfactory)	38.5	39 (Good)
PM <sub>2.5</sub>	21.05		24.5		10.75	
SO <sub>2</sub>	1.35		1.1		0.3	
NO <sub>x</sub>	20.05		20.9		14.95	

### V. CONCLUSIONS

The meteorological data for Mysuru city were collected and assimilative capacity of the study region was calculated in terms of the ventilation coefficient and pollution potential. The diurnal variation of temperature, wind speed and MMD showed a similar trend, as it was found to be minimum during morning hours and gradually increased and reached the peak at 12:00 to 16:00 h and then started decreasing in all the seasons. During winter season PM<sub>10</sub> and PM<sub>2.5</sub> concentrations were found to be exceeded at Location 1 due to low temperature (15°C), low wind speeds (2 – 8 km/h). During summer season NO<sub>x</sub> concentration was found to be more pronounce compared to winter and monsoon seasons which may be due to increase in fleet movement of vehicles in summer holidays. However, all pollutant concentrations were found to be within NAAQS at Hebbal Industrial area. The ventilation coefficient was found to be maximum during summer season (12053 m<sup>2</sup>/s at 15:00 h) followed by winter (9447 m<sup>2</sup>/s at 14:00 h) and monsoon season (8132 m<sup>2</sup>/s at 14:00 h). The ventilation coefficient values were found to be very low (< 2000 m<sup>2</sup>/s) during early

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 10, October 2017

morning (01:00 – 09:00 h) and evening/night hours (20:00 – 24:00 h), indicating a high pollution potential or low assimilative capacity of the atmosphere during these periods. During winter season PM<sub>10</sub> concentration was exceeding 90 % of guideline values at location 1 and 2, which implies a negative assimilative potential of the study area. However, during summer and monsoon seasons assimilative capacity for PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub> and SO<sub>2</sub> found to be well within the permissible limits of NAAQS. During winter season AQI was found to be ‘Moderate’ (141) at location 1 and 2, due to high pollution load of PM<sub>10</sub> (> 100 µg/m<sup>3</sup>). During summer season AQI was found to be ‘Satisfactory’ at all the locations. However, during monsoon season at location 2 and 3, AQI was found to be ‘Good’ due to the occurrence of precipitation.

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### REFERENCES

- [1] Andria, G., Cavone, G. and Lanzolla, A. M. L., “Modelling study for assessment and forecasting variation of urban air pollution”, *Measurement*, Vol. 41, pp. 222 – 229, 2008.
- [2] Baldasano, J. M., Valera, E. and Jimenez, P., “Air quality data from large cities”, *The Science of the Total Environment*, Vol. 307, pp. 141 – 165, 2003.
- [3] Banerjee, T., “Assessment and model performance evaluation of air quality at Integrated Industrial Estate-Pantnagar”, Doctor of Philosophy Thesis, Department of Environmental Science, G. B. Pant University of Agriculture and Technology, Pantnagar, India, 2010.
- [4] Banerjee, T., Barman, S. C. and Srivastava, R. K., “Application of air pollution dispersion modeling for source-contribution assessment and model performance evaluation at integrated industrial estate – Pantnagar”, *Environmental Pollution*, Vol. 159, pp. 865 – 875, 2011.
- [5] Bhanarkar, A. D., Goyal, S. K., Sivacoumar, R. and Rao, C. V. C., “Assessment of contribution of SO<sub>2</sub> and NO<sub>2</sub> from different sources in Jamshedpur region, India”, *Atmospheric Environment*, Vol. 39, pp. 7745 – 7760, 2005.
- [6] California Air Resources Board (CARB), “Initial Statement of Reasons for Rulemaking”, California Air Resources Board, Sacramento, 1998.
- [7] California Air Resources Board (CARB), EMFAC 2002 model, 2002.
- [8] Chaurasia, S., Dwivedi, P., Singh, R. and Gupta, A. D., “Assessment of ambient air quality status and air quality index of Bhopal city (Madhya Pradesh), India”, *Int. J. Curr. Sci.*, Vol. 9, pp. 96 – 101, 2013.
- [9] Englert, N., “Fine particles and human health—a review of epidemiological studies”, *Toxicology Letters*, Vol. 149, pp. 235 – 242, 2004.
- [10] Gift, J. S., McGaughy, R., Singh, D. V. and Sonawane, B., “Health assessment of phosgene: approaches for derivation of reference concentration”, *Regul. Toxicol. Pharmacol.*, Vol. 51, pp. 98 – 107, 2008.
- [11] Goyal, P., Anand, S. and Gera, B. S., “Assimilative capacity and pollution dispersion studies for Gangtok City”, *Atmos Environ*, Vol. 40, pp. 1671 – 1682, 2005.
- [12] Goyal, P., Anand, S. and Gera, B. S., “Assimilative capacity and pollutant dispersion studies for Gangtok city”, *Atmospheric Environment*, Vol. 40, pp. 1671 – 1682, 2006.
- [13] Goyal, P., Krishna, R. T. V. B. P. S. and Anand, S., “Assimilative capacity and dispersion of pollutants in Delhi”, *Proc Indian NatlSciAcad*, Vol. 69, pp. 775 – 784, 2003.
- [14] Goyal, S. K. and Rao, C. V. C., “Assessment of atmospheric assimilation potential for industrial development in an urban environment: Kochi (India)”, *Science of the Total Environment*, Vol. 376, pp. 27 – 39, 2007.
- [15] Gross, E., “The National Air Pollution Forecast Programme”, ESSA Technical Memo., WBTM-NMC 47, US Department of Commerce, 1970.
- [16] Gurjar, B. R., Butler, T. M., Lawrence, M. G. and Lelieveld, J., “Evaluation of emissions and air quality in megacities”, *Atmospheric Environment*, Vol. 42, pp. 1593 – 1606, 2008.
- [17] Guttikunda, S. K., Carmichael, G. R., Calori, G., Eck, C. and Woo, J. H., “The contribution of megacities to regional sulfur pollution in Asia”, *Atmospheric Environment*, Vol. 37, pp. 11 – 22, 2003.
- [18] Health Effects Institute (HEI), “Diesel Exhaust, A Critical Analysis of Emissions, Exposure, and Health Effects”, Health Effects Institute, Diesel Epidemiology Working Group, Boston, MA, 1995.
- [19] Health Effects Institute (HEI), “Research Directions to Improve Estimates of Human Exposure and Risk from Diesel Exhaust”, Health Effects Institute, Diesel Epidemiology Working Group, Boston, MA, 2002.
- [20] Kansal, A., Khare, M. and Sharma, C. S., “Air quality modelling study to analyse the impact of the World Bank emission guidelines for thermal power plants in Delhi”, *Atmospheric Pollution Research*, Vol. 2, pp. 99 – 105, 2011.
- [21] Kilburn, K. H., Hudson, A. R., Halprin, G. M., McKenzie, W. N. and Merchant, J. A., “Two patterns for bronchial damage from inhaled materials”, *Chest*, Vol. 65, pp. 61S – 62S, 1974.
- [22] Kodavanti, U. P., Ledbetter, A. D., Thomas, R. F., Richards, J. E., Ward, W. O., Schladweiler, M. C. and Costa, D. L., “Variability in ozone-induced pulmonary injury and inflammation in healthy and cardiovascular-compromised rat models”, *Inhal. Toxicol.*, Vol. 27, pp. 39 – 53, 2015.

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Vol. 6, Issue 10, October 2017

- [23] Krishna, R. T. V. B. P. S., Reddy, M. K., Reddy, R. C. and Singh, R. N., "Assimilative capacity and dispersion of pollutants due to industrial sources in Visakhapatnam bowl area", *Atmospheric Environment*, Vol. 38, pp. 6775 – 6787, 2004.
- [24] Kumar, S. S. and Kriti, S., "Ambient Air Quality Status of Jaipur City, Rajasthan, India", *International Research Journal of Environment Sciences*, Vol. 5, pp. 43 – 48, 2016.
- [25] Lelieveld, J., Crutzen, P. J., Ramanathan, V., Andreae, M.O., Brenninkmeijer, C. A. M., Campos, T., Cass, G. R., Dickerson, R. R., Fischer, H., de Gouw, J. A., Hansel, A., Jefferson, A., Kley, D., de Laat, A. T. J., Lal, S., Lawrence, M. G., Lobert, J. M., Mayol-Bracero, O. L., Mitra, A. P., Novakov, T., Oltmans, S. J., Prather, K. A., Reiner, T., Rodhe, H., Scheeren, H. A., Sikka, D. and Williams, J., "The Indian Ocean Experiment: Widespread Air Pollution from South and Southeast Asia", *Science*, Vol. 291, pp. 1031 – 1036, 2001.
- [26] Li, W. L. and Pauluhn, J., "Comparative assessment of the sensory irritation potency in mice and rats nose-only exposed to ammonia in dry and humidified atmospheres", *Toxicology*, Vol. 276, pp. 135 – 142, 2010.
- [27] Lightly, J. S., Veranth, J. M. and Sarofin, A. F., "Combustion aerosols: factors governing their size and composition and implications to human health", *Journal of the Air and Waste Management Association*, Vol. 50, pp. 1565 – 1618, 2000.
- [28] Luo, S., Trübel, H., Wang, C. and Pauluhn, J., "Phosgene- and chlorine-induced acute lung injury in rats: comparison of cardiopulmonary function and biomarkers in exhaled breath", *Toxicology*, Vol. 326, pp. 109 – 118, 2014.
- [29] Maji, S., Ahmed, S. and Siddiqui, W. A., "Air quality assessment and its relation to potential health impacts in Delhi, India", *Current Science*, Vol. 109, pp. 902 – 909, 2015.
- [30] Manju, N., Balakrishnan, R. and Mani, N., "Assimilative capacity and pollutant dispersion studies for the industrial zone of Manali", *Atmospheric Environment*, Vol. 36, pp. 3461 – 3471, 2002.
- [31] Nandankar, P. K., "Assimilative capacity of the atmosphere at Lucknow with respect to air pollution", *Mausam*, Vol. 50, pp. 263 – 268, 1999.
- [32] National Ambient Air Quality Standards (NAAQS), "Central Pollution Control Board Notification, the Gazette of India", Extraordinary, New Delhi, 2009.
- [33] Padmanabhamurthy, B. and Mandal, B. B., "Climatology of inversions, mixing depth and ventilation coefficients at Delhi", *Mausam*, Vol. 30, pp. 473 – 478, 1979.
- [34] Prakash, B. M., Mahadevaswamy, M., Mahesh, S. and Sharadhini, S. R., "Air Quality Assessment along the Highway Due to Vehicular Emissions and Validation of Air Quality Monitored Data with the CALINE4 Model", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 4, pp. 8369 – 8376, 2015.
- [35] Prakash, B. M., Mahadevaswamy, M., Mahesh, S. and Vishala, N., "Prediction of Air Pollutants Dispersion Emitted from Point and Line Sources along the Highway Passing Through Industrial Area of Mysuru - AERMOD and CALINE4 Models", *International Journal of Innovative Research in Science, Engineering and Technology*, Vol. 5, pp. 14497 – 14508, 2016.
- [36] Ramanathan, V., Crutzen, P. J., Lelieveld, J., Mitra, A. P., Althausen, D., Andersons, J., Andreae, M. O., Cantrell, W., Cass, J. R., Chung, C. E., Clarke, A. D., Coakley, J. A., Collins, W. D., Conant, W. C., Dulac, F., Heintzenberg, J., Heymsfield, A. J., Holben, B., Howell, S., Hudson, J., Jayaraman, A., Kiehl, J. T., Krishnamurti, T. N., Lubin, D., McFarquhar, G., Novakov, T., Ogren, J. A., Podgorny, I. A., Prather, K., Priestley, K., Prospero, J. M., Quinn, P. K., Rajeev, K., Rasch, P., Rupert, S., Sadourny, R., Sathesh, S. K., Shaw, G. E., Sheridan, P. and Valero, F. P. J., "Indian Ocean Experiment: An integrated analysis of the climate forcing and effects of the great Indo-Asian haze", *Journal of Geophysical Research*, Vol. 106, pp. 28371 – 28398, 2001.
- [37] Rao, S. S., Rajamani, N. S. and Reddi, E. U. B., "Dispersal Conditions and Assimilative Capacity of Air Environment at Gajuwaka Industrial Hub in Visakhapatnam", *IJRSET*, Vol. 1, pp. 5 – 15, 2015.
- [38] Sarella, G. and Khambete, A. K., "Ambient Air Quality Analysis using Air Quality Index – A Case Study of Vapi", *International Journal for Innovative Research in Science & Technology*, Vol. 1, pp. 68 – 71, 2015.
- [39] Sharma, S. and Chandra, A., "Simulation of Air Quality using an ISCST3 Dispersion Model", *Clean – journal*, Vol. 36, pp. 118 – 124, 2008.
- [40] Singh, G. and Perwez, A., "Estimation of Assimilative Capacity of the Airshed in Iron Ore Mining Region of Goa", *Indian Journal of Science and Technology*, Vol. 8, pp. 1 – 6, 2015.
- [41] Singh, M. P., Goyal, P., Panwar, T. S., Agarwal, P., Nigam, S. and Bagchi, N., "Predicted and observed concentrations of SO<sub>2</sub>, SPM and NO<sub>x</sub> over Delhi", *Atmospheric Environment*, Vol. 24A, pp. 783 – 788, 1990.
- [42] Stack-Pole, J. D., "The Air Pollution Potential Forecast Programme", *ESSA Tech., Memo, WBTM-NMC 43*, 1967.
- [43] Thawonkaew, A., Thepanondh, S., Sirithian, D. and Jinawa, L., "Assimilative capacity of air pollutants in an area of the largest petrochemical complex in Thailand", *International Journal of GEOMATE*, Vol. 11, pp. 2162 – 2169, 2016.
- [44] Thepanondh, S. and Jitbantoung, N., "Assimilative Capacity Analysis of Air Pollutants over the Dawai Industrial Complex", *International Journal of Environmental Science and Development*, Vol. 5, pp. 161 – 164, 2014.
- [45] Thilagaraj, P., Ravinder, R. and Kesavan, R., "A Study on Air Pollution and its Impact on Human Health in Chennai City", *IOSR Journal of Mechanical and Civil Engineering*, pp. 1 – 5, 2014.
- [46] Tuck, S. A., Barbón, D. R., Campbell, H., McGovern, T., Quintana, H. K. and Martin, J. G., "Time course of airway remodelling after an acute chlorine gas exposure in mice", *Respiratory Research*, Vol. 9, pp. 1 – 16, 2008.
- [47] Turner, D. B., "Workbook of Atmospheric Dispersion Estimates", Washington, DC, 1969.
- [48] Viswanadham, D. V. and Kumar, A. K. G., "Diurnal, monthly and yearly variation of mixing heights and ventilation coefficient for Cochin", *Indian Journal of Environmental Protection*, Vol. 9, pp. 38 – 47, 1989.
- [49] Wang, T., Ding, A. J., Blake, D. R., Zahorowski, W., Poon, C. N. and Li, Y. S., "Chemical Characterization of the Boundary Layer Outflow of Air Pollution to Hong Kong During February-April 2001", *J. Geophys. Res.*, Vol. 108, pp. 8-1 – 8-15, 2003.
- [50] Wang, T., Poon, C. N., Kwok, Y. H. and Li, Y. S., "Characterizing the Temporal Variability and Emission Patterns of Pollution Plumes in the Pearl River Delta of China", *Atmos. Environ.*, Vol. 37, pp. 3539 – 3550, 2003.
- [51] Weather underground, (2017) Station Mysore, India, Retrieved from <https://www.wunderground.com/q/zmw:00000.46.43291?sp=VOMY>.