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INFLUENCE OF VEHICULAR TRAFFIC ON URBAN AIR QUALITY-COIMBATORE CITY

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Abstract - *Vehicular traffic is growing at a higher rate contributing to increased air pollution levels. Management of traffic operation in urban areas of India has become a huge task to the concerned authorities. Despite all the efforts, traffic congestion is still continuing, leading to rapid environmental degradation. In this paper an attempt has been made to study the traffic characteristics, traffic quantification and air quality index due to vehicular emission in a major road network in Coimbatore city. Air quality data were collected along five major traffic signals in Avinashi road i.e. Lakshmi mills, Peelamedu, Hopes, CMC and Sitra for a period of five months. Traffic congestion studies have been conducted to know the prevailing traffic volumes on the existing roads. The results obtained from facts of existing situation and important issue posed due to transport was utilized to model the air pollution as a function of traffic and roadway parameters for future predictions using CALINE4 modeling.*

Key Words: **Air Quality Index (AQI), Air Pollution, Traffic Studies, Vehicular Emission, Ambient Air**

1. INTRODUCTION

The economic development of a particular region depends on its easy access to goods and people, which is ensured by transport technology. Unfortunately, all these positive aspects are interlinked with environmental degradation and health hazards. Transportation sector contributes around 70% of total environmental pollution in urban areas. Uncontrolled vehicular traffic is the primary reason for emerging air pollution. The prime sources of air pollutants include particulate matters (PM_{10}& $PM_{2.5}$), SO_2, NO_x and CO. These pollutants are responsible for ill-effects such as cardiovascular diseases and respiratory problems. Thus, the scientific technologies are constantly seeking for alternate new technologies to understand and improve the atmosphere composition. Motorcycles contribute about 16% of the total CO emission. According to the recent studies from the S� Paulo State (Brazil), vehicles are responsible for 97% of CO emission, 40% of particulate matter (PM), 36% of SO_2 and 82% of nitrogen oxides (NO_x).

In emerging countries like China, India and Brazil, motorcycles are rising in higher number day to day. In India, the problem of air pollution in the urban areas have become so remarkable due to the absence of efficient, effective and well networked transport system, Lack of fast railway network which can run on cleaner technologies, bad road conditions, older vehicles and adulterated fuels. Population density and rapid urbanization imposes immense pressure upon public transport. This leads to excessive use of private vehicles imposing congestion on roads resulting in more pollution. Air pollution modelling is based on various models like Gaussian models, Box models, computational dynamic models and plume models. Air quality dispersion modelling acts as an important tool in predicting the air quality against National Ambient Air Quality Standards (NAAQs) and the results are useful in the air pollution management. CALINE 4 is one such dispersion model used for predicting air pollution concentration near roadways.

2. STUDY AREA

2.1. Description of study area

Coimbatore is the second largest city by area and population in Tamil Nadu after Chennai. The city has three National highways and six major arterial road network. Coimbatore is called Manchester of South India for its extensive textile industries. The city is thickly populated [1] and has moderately ventilated air basin which is being polluted due to many activities such as ever-expanding transport, commercial activities and construction. Hence, for the purpose of deriving comprehensive air pollution control strategies it is necessary to forecast the impacts of air pollutants emitted from various sources.

2.2. Description of sampling site

Avinashi road is one of the main gateways into Coimbatore city. This road is a hub for many Educational Institutions, Corporate offices, IT parks, Luxury hotels and Hospitals. The major source of air pollution in the study was found to be due to vehicular emissions. Five sampling site selected for Ambient Air Quality (AAQ) monitoring in Coimbatore. They are Lakshmi mills signal, Peelamedu signal, Hopes Junction, Coimbatore Medical College Signal and Sitra airport.

The selected road network sites were places of heavy traffic, maximum population and commercial as well as educational activities. A continuous sampling has been carried out twice a week for a period of five months (October 2018 to February 2019) during peak traffic hours from 8.00 a.m. to 4.00 p.m.

Fig. 1. Vehicular junction points in the study area

3. MATERIALS AND METHODS

3.1. Methodology

The sampling and analysis has been done as per Indian standard methods of measurement of Air Pollution: IS: 5182 (Part IV) 1973. The real-time Carbon monoxide concentrations, wind speed, traffic flow, and wind angle figures are obtained simultaneously by roadside monitoring. Wind speed and wind angle is measured at (5 m away from mixing zone width) from monitoring stations (Data is provided by CRRI, New Delhi). The weighted emission factors WEF (gm−1) of Indian vehicles are used from literature ([2],[3]). The hourly mixing height values are taken from Indian Meteorological Department (IMD) [4]. Traffic characteristics data (traffic flow and weighted emission factors) and meteorological data (wind speed, wind angle, mixing height etc.) is used as an input parameter in CALINE4/CL4v2.1 for CO prediction.

3.2. Micro-meteorology

Dispersion of air pollutants is influenced by various meteorological parameters which include: temperature, wind speed, wind direction, relative humidity, nature of terrain and mean mixing depth (MMD). Meteorological data was obtained for Avinashi road, which were used for plotting annual variation of average wind speed, temperature, relative humidity and wind rose plot from October, 2018 to February, 2019. It was observed that, temperature was found to be maximum during February when compared to post-monsoon and winter season (October to January). The predominant wind was blowing from North-East to South-West during this period.

Table -1 Meteorological Parameters

Month	Ambient Temperature (°C)	Pressure (hPa)	Wind Speed (m/s)	Humidity (%)
October	26	1014	4	59
November	25	1013	3	67
December	21	1011	5	75
January	23	1013	4	61
February	27	1015	3	45

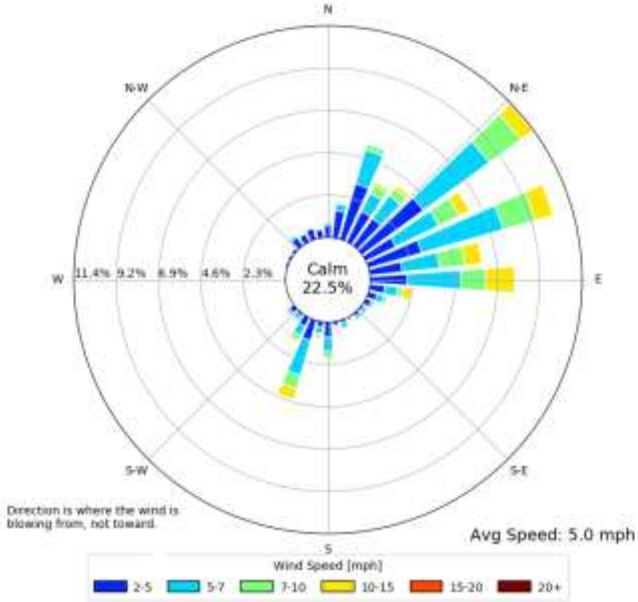

Fig. 2. Windrose plot from Oct 2018 to Feb 2019

3.3. Traffic counting at sampling sites

Five traffic junction points were selected for vehicular pollution monitoring as well as traffic studies. Hourly traffic counting was carried out at different junction through road networks for different category of vehicles (2 wheelers, 3 wheelers, Light duty and heavy duty vehicles) during 8.00 to 16.00 hours. Receptors were located nearer to roadway where pollutant concentrations that are caused due to mobile sources are to be measured. Avinashi road network is one of the busiest networks in Coimbatore. Large number of vehicles moves on the road. The entire road network has two way traffic systems consisting of six lanes. The distribution of automobile vehicles that were plying during the sampling period at these five locations is depicted in a pie chart shown below

Table -2 Traffic Volume and Study Details

Code	Location	Traffic Count (approx. per day)	PCU	Performance
1	Laskshmi Mills	19355	47321	Fair
2	Peelamedu	18395	49795	Fair
3	Hopes	21152	52633	Fair
4	CMC Signal	18162	49374	Fair
5	Sitra	19962	46862	Fair

Table -3 Distribution of Automobile Vehicles (in %)

Location Code	2 Wheelers	3 Wheelers	LMV	HMV
1	**58**	**10**	**22**	**10**
2	**67**	**3**	**16**	**8**

3	69	11	11	9
4	63	11	14	12
5	62	12	14	12

4. MODELLING

4.1. CALINE4 Model Description

CALINE4 model is the fourth generation line source Gaussian plume dispersion model. CALINE4 model predicts the concentrations of suspended particles ($PM_{10}/PM_{2.5}$), Nitrogen dioxide (NO_2) and carbon monoxide (CO) near roadways. This model can predict the pollutant concentrations for receptors that are located within 150m, given their traffic and meteorological conditions.

4.2. Inputs for CALINE4 [5]

i) Traffic parameters: Traffic volume (hourly and peak), traffic composition (two wheelers, three wheelers, cars, buses, goods vehicle etc.), type of the fuel used by each category of vehicles, fuel quality, average speed of the vehicles.
ii) Meteorological parameters: Wind speed, wind direction, stability class, mixing height.
iii) Emission parameters: Expressed in grams /distance travelled. Different for different categories of vehicles and is a function of the type of the vehicle, fuel used, average speed of the vehicle and engine condition.
iv) Road geometry: Road width, median width, length and orientation of the road, number and length of each links.
v) Type of the terrain: Urban or rural, flat or hilly.
vi) Background concentration of pollutants.

4.3. Traffic and Road Geometry Data

CALINE4 modeling requires a comprehensive set of input information on traffic volume, traffic composition, emission factors and road geometry for different vehicular fleets. Traffic composition data was collected from all sites of Coimbatore City along Avinashi road. Traffic volume (peak and hourly), traffic composition, fuel quality, average speed of the vehicles was collected. Road geometry includes the road and median width, orientation and length of the road, number and length of each link were calculated. In India, two sets of emission factor have been calculated by Indian Institute of Petroleum (IIP) and Automotive Research Association of India (ARAI), Pune. In this study, CO emission norm for Indian vehicles established by Indian Institute of Petroleum (IIP) [6] was used.

Table -4 Emission Factor Calculation by the Indian Institute of Petroleum (IIP)

Vehicle type	CO (g/km)	NO_x (g/km)	SO_2 (g/km)	Particulate (g/km)
Two wheeler	8.30	-	0.013	-
Four wheeler	24.03	1.57	0.053	-
Three Wheeler	12.25	-	0.029	-
Urban Buses	4.381	8.281	1.441	0.275
Trucks	3.425	6.475	1.127	0.450
Light Commercial vehicle	1.30	2.50	0.40	0.100

4.4. Emission Factor

Vehicular CO emission for each link taken as average weighted emission was calculated by multiplying the number of vehicles by their respective type with corresponding emission factor and it is summed up. To provide inputs to the source strength of the models, the emission factors were further combined to calculate the composite Emission Factor. The composite emission factor [7] was calculated for four categories of vehicles using Equation (1).

$$EF_C = \frac{(EF_1 \times V_1) + (EF_2 \times V_2) + (EF_3 \times V_3) + (EF_4 \times V_4)}{\Sigma V} \quad (1)$$

Table -5 CO Emission Factor for vehicles

S.No	Type of Vehicle	CO (g/km)
1	Four wheeler	23.4
2	Three wheeler	13.2
3	Two wheeler	7.9
4	Truck	3.425
5	Bus	4.38

5. RESULTS AND DISCUSSION

A continuous monitoring in order to evaluate the pollutant levels of SPM, NO_x, SO_2 and CO in ambient air of Coimbatore city has been carried out. Five different pollution prone locations were intentionally identified and 8 hours sampling was carried out during peak hours from 8.00 a.m. to 4.00 p.m. The monitoring was done twice a week for a period of five months (i.e. October 2018 to February 2019). The results from the monitoring are displayed in graph below as yearly mean concentration and compared with NAAQs standards [8].

5.1. Suspended Particulate Matter (SPM)

The mean concentration value of suspended particulate matter (SPM) at the five locations for five months were 342 $\mu g/m^3$, 350 $\mu g/m^3$, 384 $\mu g/m^3$, 325 $\mu g/m^3$ and 335 $\mu g/m^3$ respectively as shown in Figure IV. The highest SPM level at Avinashi road was in AAQ 3, Hopes signal due to narrowed roadway, vehicle queuing, acceleration and deceleration, idling in the area. The pollution is mainly due to emission

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from vehicles and suspension of traffic dust. The mean value of suspended particulate matter (SPM) was found to be highest at Hopes junction and lowest at CMC signal. The level of SPM was observed above the safety limits at all five locations.

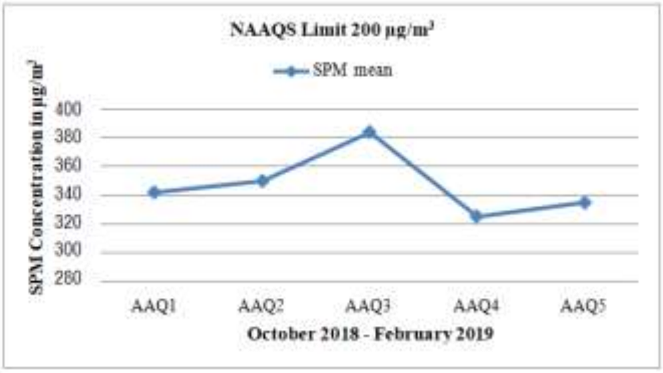

Chart 1: Mean concentration (µg/m^3) of SPM at different sites of Avinashi road

5.2. Sulphur dioxide (SO_2)

The mean concentration value of Sulphur dioxide (SO_2) at the five locations for five months were 48 µg/m^3, 50 µg/m^3, 53 µg/m^3, 35 µg/m^3 and 43 µg/m^3 respectively as shown in Figure V. The average level of $SO_2$was below the permissible limit (80 µg/m^3) as prescribed by NAAQS at all five locations.

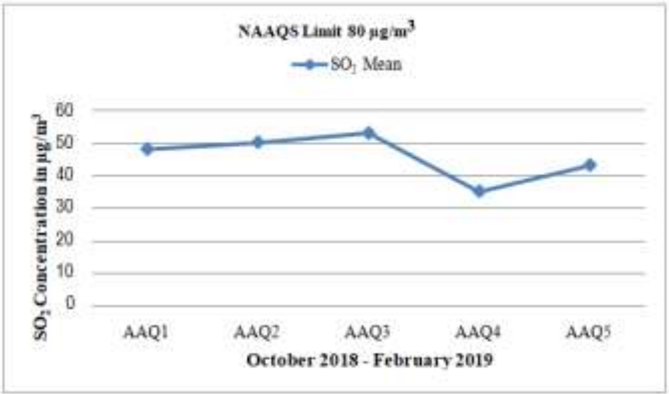

Chart 2: Mean concentration (µg/m^3) of SO_2 at different sites of Avinashi road

5.3. Oxides of Nitrogen (NO_x)

The mean concentration value of Oxides of Nitrogen (NO_x)at the five locations for five months were 80 µg/m^3, 78 µg/m^3, 81 µg/m^3, 67 µg/m^3 and 79 µg/m^3 respectively as shown in Figure VI. The highest NO_x level at Avinashi road was in AAQ 3, Hopes signal. The mean value of suspended particulate matter (SPM) was found to be highest at Hopes junction and lowest at CMC signal. The mean of NO_x exceeds the prescribed NAAQS (80 µg/m^3) limit at Hopes and Lakshmi mills Junctions. This road is busy for almost 24 hours. The pollution due to oxides of nitrogen is mainly occurs from two and three wheelers, poor fuel quality, violation of emission norms, lacking in vehicle maintenance, erratic traffic behavior leading to congestion, older vehicle engine technology, inadequate traffic management and adulteration of fuel.

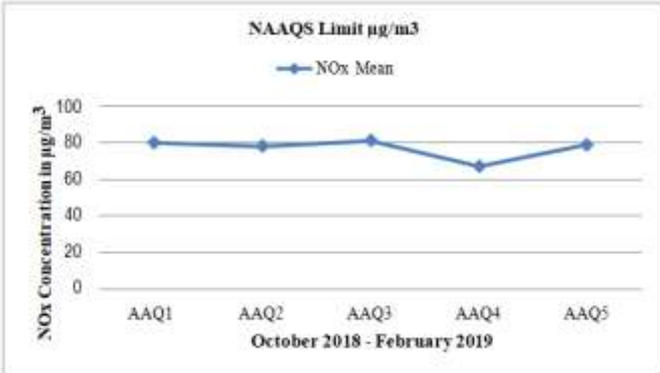

Chart 3: Mean concentration (µg/m^3) of NO_x at different sites of Avinashi road

D. Carbon Monoxide (CO)

The mean value of CO at five monitoring locations were 1.98 mg/m^3, 2.15 mg/m^3, 2.10 mg/m^3, 1.50 mg/m^3 and 1.73 mg/m^3 respectively as shown in figure VII. The highest CO Level was in Peelamedu signal due to higher emission of carbon monoxide and hydrocarbons from 2 and 3 wheelers consisting of two stroke engines.

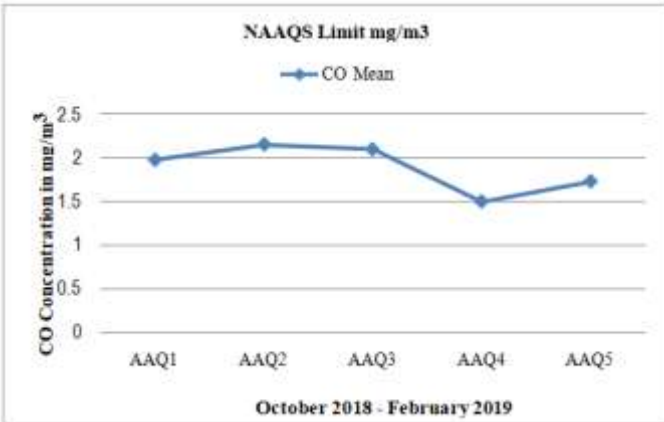

Chart 4: Mean concentration (mg/m^3) of CO at different sites of Avinashi road

5.4. Comparison between Monitored CO and CALINE4 Model

In this section, CO concentration values observed during field survey is compared with those obtained by CALINE4. The stimulation was made for the traffic conditions prevailing in October 2018 to February 2019 and compared with CO concentration measured at the same period.

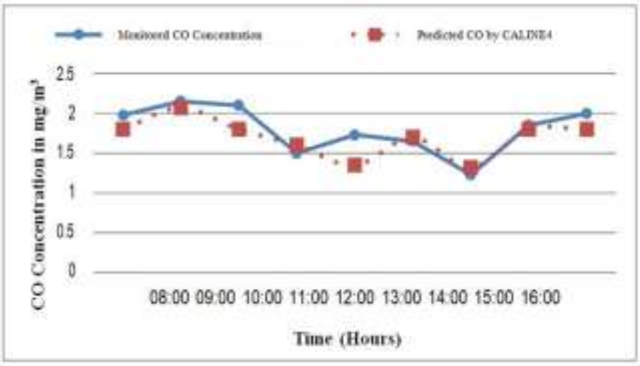

Chart 5: Plot of predicted CO & Monitored CO concentration using CALINE4

The results show that the predicted CO resulting from CALINE 4 model are in between the observed hourly field values. CALINE4 model is in good agreement with the observed field values. The observed CO concentrations at the traffic junctions are more or less close to that of the predicted values using CALINE4.

6. CONCLUSION

This paper has concentrated on modeling of traffic related CO emission along Avinashi road due to its large impact on environment and human health. Real-time traffic related near road CO concentration was monitored in five signals. These data bases were used for evaluating its suitability for line source modeling in CALINE4 model. With respect to hourly modeling of CO, CALINE4 indicated more appropriate values from vehicular traffic. It was also found that Suspended Particulate matter is the main contributor in air pollution. Particulate matters are ground level sources which highly impact human health. The present study highlights the CALINE4 application which can be used for air quality management purposes along the road/ highway corridor(s). Therefore CALINE4 dispersion model are in good agreement with observed values.

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