INFLUENCE OF HIGHWAY TRAFFIC ON INTENSITY OF CARBON MONOXIDE IN AMBIENT AIR

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ABSTRACT

The impact of vehicular emissions on urban air pollution has caused increasing public attention. Originally urban air pollution was considered as a local problem mainly associated with domestic heating and industrial emissions, which are now controllable to a great extent. Despite significant improvements in fuel and engine technology, present day urban environment are mostly dominated by traffic emissions. It is now generally recognised that many of substances directly emitted by vehicles in the ambient air represent a serious hazard for human health. Transportation and environmental engineers are jointly responsible for the studies related to air pollution like, assessment of air quality, calibrations of models available elsewhere and for developing models for prediction of air quality.

In the present study, an attempt was made to measure carbon monoxide levels in ambient air adjacent to National Highway in the suburban area of New Delhi. Traffic data was also collected simultaneously for duration of 24 hours on a normal working day. CO intensities were analysed over different times of the day and compared with the threshold limits. A linear regression model was developed to predict the CO levels in ambient air as function of traffic parameters.

1.0 INTRODUCTION

All outdoor environments are subjected to the same regulatory standards for ambient air quality, whereas roadside concentrations differ significantly from these background levels. This is due to assumption that pollutant concentrations observed at a single or a few monitoring stations within a city are representative of exposure of the entire urban population. In urban environments and especially in those areas where population and traffic density are very high, human exposure to hazardous substances is expected to be significantly increased. This is often the case near busy traffic intersections in city centers, where urban topography and microclimate may contribute to creation of poor dispersion conditions giving rise to contamination hotspots.

The air pollution due to automotive vehicle emission has assumed an alarming magnitude and poses a potential threat to the very existence of healthy life. In India, over the past 50 years, approximately 37.2 million vehicles have been registered and this number may shoot up further in future (Ramakrishna S and Ravikumar Reddy C 2001). The increase in number of vehicles would certainly worsen the air quality in future. Carbon monoxide (CO), an invisible odourless gas, created when fuels containing carbon are burned incompletely, poses a serious threat to human health. Therefore, the monitoring of CO concentrations in the ambient air is necessary and efficient measures are to be taken to keep the CO levels well below the standards. Considerable sources are often devoted to measurement of air pollutant concentrations in the ambient atmosphere, but measurements on their own provide little information on the origin of pollutant under question, and the meteorological parameters that effect the concentration of CO in ambient air. The traffic parameters influence the CO concentrations to a great extent. Therefore, frequently, there is a need for detailed knowledge of characteristics and quantities of pollutant emitted the traffic parameters and meteorological factors, which govern the subsequent dispersal and fate.

1.1 Air Quality Monitoring

Now a days, automated monitoring networks operate in many European cities providing detailed air quality information on a regular basis. There are several techniques available for monitoring gaseous pollutants (e.g., continuous monitoring using standard gas analyzers, diffusive and pumped sampling using tubes filled with an appropriate adsorbent, grab sampling using canisters) and particulate matter (e.g., filtration and impaction).

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The response time is time over which the sample is taken and is one of the major factors that determine the suitability of a method. Standard gas analyzers are sufficiently sensitive and fast to give real time (i.e. typical response time 1-2 minutes) measurements of CO, NOx and O_3 concentrations. The results can then be averaged over short time periods and compared to the regulatory standards. Diffusive samplers have a relatively long response time (e.g., 1-2 days to 4 weeks), which make them less suitable for observing atmospheric pollutants responsible for short term health effects. On the other hand long response times might be preferable when sampling substances like benzene, whose impact on human health is due to cumulative exposure.

1.2 Air Pollution Scenario Due to Transportation

The air pollution due to automotive vehicle emission has assured an alarming magnitude and poses a potential threat to the very existence of a healthy life. This can be amply demonstrated from the United States statistics that out of 142 million tons of pollutants that are given of to air every year, industries account for 20 million tons, space heating for 8 million tons, refuse disposal for 5 million tons and motor vehicles for 80 million tons (S N Bandyopadhyah, 1996). On global scale data published by Sinha et al., (1989) show that vehicles are responsible for 22% global manmade CO_2 emissions and 28% of global energy consumption. About 75 to 95% of emissions from mobile sources stem from road transport (Faiz 1991).

In a rapidly urbanizing country, like, India, the transportation sector is growing rapidly and the number of vehicles on Indian roads is increasing at a rate of more than 7% per annum. As per estimates of RITES, the likely number of vehicles by the year 2010 could reach 1475.01 lakh (Ray, Amit, 2001). This has lead to overcrowded roads and polluted environment. The transportation sector is the main contributor to the ever-increasing air pollutant concentrations in our many metropolitan cities. According to a study, cars and two-wheelers contribute to 11%and 78% of the total transport related air pollution and vehicles are responsible for 64% of total air pollution load.

1.3 Pollutants Due To Vehicular Traffic

Transportation is the main reason for air pollution in urban areas. Automobiles cause 60% to 80 % of the air pollution (S Vijay Kumar, 1997). It is because of rapid and unplanned urbanisation.

Major pollutants emitted from vehicles are Carbon monoxide (CO) and Carbon dioxide (CO2), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Lead (Pb), Particulate Matter (PM), Hydrocarbons (HC), Toxic compounds. Emissions from automobiles are broadly classified into three categories.

- **Exhaust emissions:** About 65-70% occurs by exhaust emissions. Carbon monoxide (CO), oxides of nitrogen (NOx), Hydrocarbons (HC), Oxides of Sulphur (SOx), and partially burnt products like aldehydes and formaldehydes, lead compounds, carbon (C) are emitted exclusively in exhaust gases. Carbon monoxide is a colourless poisonous gas; it is slightly lighter than air; and incomplete burning of carbon in automobile fuels produces it. NOx is produced when the fuel is burnt at very high temperature.
- **Crank Case Emissions:** 20 % of emissions occur through blow by gases from crankcase. These emissions are unburnt hydrocarbons from crankcase ventilation system. This system recycles crankcase ventilation air and blow gases to the engine intake, instead of venting them in to the atmosphere.
- **Evaporative Emissions:** These emissions contain only hydrocarbons. These are due to evaporation from fuel tank and carburetor. An average Indian passenger car would emit about 20Kg of HC annually. It contributes about 20 % of total HC emission.

1.4 Petrol engines, Diesel engines and Compressed Natural Gas (CNG)

In petrol engine, petrol and air in relatively constant proportions are mixed in the carburetor drawn in to engine, compressed and ignited by a spark. When fuel burns completely, the exhaust products are water, carbon dioxide and oxides of nitrogen, which are harmful (it is not in practice.) The exhaust then additionally contains CO, HC (unburnt hydrocarbons), hydrogen and small amounts of oxides of sulphur and lead.

CO and HC concentrations at idle and deceleration are comparatively higher. This appears to be because of little air reaching the cylinders, while the quantity of fuel remains high at least during the beginning of operations. It is, therefore, evident that a petrol driven vehicle operating under partial load and speed will yield reasonably complete combustion and thus a cleaner exhaust, at all other times it is likely to be incomplete.

In Diesel engines, only air is compressed instead of fuel air mixture as that in petrol engine. Then the fuel is injected into the cylinders, and the fuel ignites by hot air, heated due to the compression without the aid of sparks. Incomplete burning produces carbon rather than carbon monoxide (CO) as in the case of petrol engines. The carbon (C) is evident in exhaust gas as black smoke. Hydrocarbons (HC) are also generally low in terms of concentration. Diesel vehicles create relatively minor pollution problems as compared to petrol driven vehicles. The major problems of diesel engines are smoke and odour. Particulates in diesel exhausts are dangerous. The particulate that pose the greatest health danger are inhalable, even micron to sub micron size particles. Natural gas can either be stored on board a vehicle as compressed natural gas (CNG) at 3,000 or 3,600 psi or as liquefied natural gas (LNG) at typically 20-150 psi. The interest in natural gas as an alternative fuel stems mainly from its clean burning qualities, its domestic resource base, and its commercial availability to end-users. Because of the gaseous nature of this fuel, it must be stored onboard a vehicle in either a compressed gaseous state (CNG) or in a liquefied state (LNG). Commercially available medium- and heavy-duty natural gas engines have demonstrated over 90% reduction of CO and particulate matter and over 50% reduction in NO_x relative to commercial diesel engines.

Co Concentrations and Its Ill Effects

CO is a poisonous inhalant. When it is inhaled, it passes through lungs and diffuses in to the blood. CO has a great affinity for combining with the hemoglobin, which is present in blood. The combination of CO with hemoglobin leads to formation of carboxy hemoglobin (COHb). The hemoglobin absorbs CO 200 times more than that of Oxygen. Therefore CO will be absorbed in to the blood instead of Oxygen, which reduces the Oxygen carrying capacity to tissues. The lack of oxygen causes severe headache and it may lead to death. Generally, urban busy traffic streets contain CO concentration of 5 to 20 ppm; cigarette smoke contains 400 to 450 ppm of CO. When CO is greater than 750 ppm, death can occur within a short period? If CO concentration is 250 to 500 ppm people will experiences less consciousness. Impaired lung functioning affects central nerve systems, changes occur in cardiac functions, difficulty in breathing. The permissible CO concentration in ambient air, suggested by many countries, are presented in Table 1.

Table 1: Permissible CO Levels Suggested By Different Countries

S no	Country/Agency	Time weighted Average	Concentration in ambient air
1	India, Central Pollution Control Board, (CPCB), 2003	8-Hour 1-Hour 8-Hour 1-Hour	2.0 mg/m^3 (Residential areas) 4.0 mg/m^3 (Residential areas) 5.0 mg/m^3 (Industrial areas) 10.0 mg/m^3 (Industrial areas)
2	Australia, NEPC, 1998	8-Hour	9.0 ppm
3	UK, National Air Quality Standards	8-Hour	10.0 ppm
4	USA, National Ambient Air Quality Standards, 1997	8-Hour 1-Hour	9.0 ppm 35.0 ppm
5	World Bank Standards	8-Hour	10.0 mg/m^3
6	WHO, Air Quality Guidelines for Europe	30 minute 15 minute	60 mg/m^3 100 mg/m^3
7	Thailand, Emission Standards for In-Use Motor Vehicles	At idle and no load	4.5 % of volume
8	Indonesia	8-Hour	20.0 ppm

2.0 CASE STUDY DETAILS

2.1 Project Road and Site Description

Delhi, the capital city of India situated in the northern part of the country is a focal point of five National Highways. To assess the traffic impacts on CO levels in ambient air in suburban area of Delhi, study is carried out at Shingu border on NH-1 (Delhi to Amritsar). This corridor is four-lane divided carriageway, which caters to traffic between Delhi and Chandigarh. The CO data, traffic data and meteorological data are monitored at a single point of the road. The spread of primary pollutants, when modelling longitudinally and laterally in the form of a profile was expected to show correlation with the character of the traffic and meteorological parameters.

2.2 Monitoring of Pollutants and Meteorological Parameters

The Carbon monoxide levels were monitored using the personal CO analyser i.e., AC-21M manufactured by Environment S. A France. The personal CO monitor has been placed on the outer edge of kerb and the CO levels are monitored every 15 minutes and the hourly average has been calculated.

Various meteorological parameters such as wind speed; wind direction, temperature and relative humidity were collected simultaneously along with the ambient air quality measurements. These meteorological parameters were collected at the study site. The average wind speed, temperature, relative humidity and wind directions on hourly basis were collected on site using Dust Monitor System, Enviro Check Model 107. The Housing model himself is absolutely water tight, so rain and other spill cannot enter into monitoring system. Therefore, this unit is ideal for stand-alone installation as roadside monitor, etc since it maintains its internal temperature closed to 22^0c at all times. The dust monitor system ENVIRO check works in such a way that portable 107 monitor will fit perfectly into the housing and all connections and the logic will work together. The features of the Dust Monitor System, Enviro Check Model 107 apart from continuous measurement of particles in the air (aerosols) of different sizes (PM 10, PM 2.5 and PM 1.0) at the same time are

- Automatic temperature recording.
- Automatic humidity level recording.
- Continuous measurement of wind direction and wind speed.

2.3 Traffic Surveys

Traffic studies are calculated for the purpose of assessing the impacts of air pollution due to vehicular emissions along the corridor. The traffic volume count is recorded for every 15-minute interval and presented as hourly averages. The vehicles are classified based on fuel consumption as CNG, Petrol and Diesel. Of the total traffic, petrol vehicles constituted to be 58%. Average speed of vehicles is varied between 40 to 55 kmph. The peak hour was observed to be between 6.00 pm to 7.00pm. The morning peak was between 11.00 am to 12.00 noon. The traffic volume was observed to be 29,723 vehicles per day. Table 2 presents the hourly traffic volume data for all the 24 hours.

The concentration of CO, represented as 1-Hour average and 8 –Hour average, varies with time of the day as shown in Figures 1 and 2, respectively. It can be observed from the Table 2 and Figures 1 and 2 that CO concentration in ambient air, either 1- Hour weighted average or 8- Hour weighted average, is with in the permissible limits suggested by Central Pollution Control Board (CPCB), India. The variation of 1- Hour weighted average CO concentration with corresponding traffic volume is presented in Figure 3.

Table 2 Traffic, Meteorological and CO data

TIME	CNG	Diesel	Petrol	Total	Monitored CO mg/m3	Wind speed (m/s)	Wind direction	Temp	Relative Humidity
8.00-9.00	25	252	945	1222	1.9467	0.05	WNW	14.2	91.1
9.00-10.00	25	219	892	1136	1.69435	0	WNW	11.6	100
10.00-11.00	34	295	1065	1394	1.5862	0.03	WNW	10.7	100
11.00-12.00	41	315	1151	1507	1.47805	0.13	WNW	10	100
12.00-13.00	33	358	963	1354	1.2257	0.16	NW	9.6	100
13.00-14.00	27	416	895	1338	1.18965	0.35	NW	9.3	100
14.00-15.00	40	410	1029	1479	1.1536	0.16	NNW	9.7	100
15.00-16.00	27	447	979	1453	1.442	0.64	W	10.4	100
16.00-17.00	38	402	1098	1538	1.442	0.56	ENE	13.4	95.4
17.00-18.00	43	413	1256	1712	1.55015	1.15	SE	18.2	85.2
18.00-19.00	52	490	1372	**1914**	1.2978	1.33	ESE	23.8	60.7
19.00-20.00	52	514	1185	1751	1.6583	1.42	S	24.1	59.5
20.00-21.00	43	482	763	1288	1.8746	1.52	SE	25.9	47.3
21.00-22.00	21	495	664	1180	0.46865	1	SSE	25.6	40.2
22.00-23.00	10	699	501	1210	0.75705	1.67	S	25.8	43.7
23.00-24.00	7	809	364	1180	1.98275	0.81	S	25.6	47.3
24.00-1.00	15	969	281	1265	1.69435	0.68	S	24.9	53.8
1.00-2.00	3	752	215	970	**2.9561**	0.5	S	23.7	54.9
2.00-3.00	2	806	162	970	1.2978	0.23	SSE	21.3	67.9
3.00-4.00	3	900	165	1068	1.442	0.24	SSE	21.2	69.7
4.00-5.00	8	568	184	760	1.442	0.24	WSW	20	74.4
5.00-6.00	6	373	244	623	1.442	0.15	N	18.8	77.1
6.00-7.00	11	264	334	609	1.5141	0.05	SSE	15	85.7
7.00-8.00	26	234	542	802	1.442	0	S	14.65	90.3

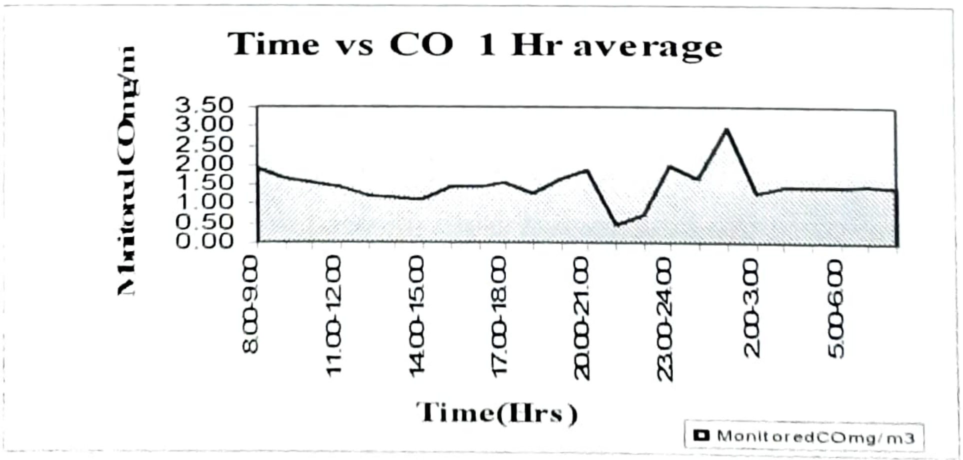

Figure 1 Variation of CO 1 Hr averages with Time

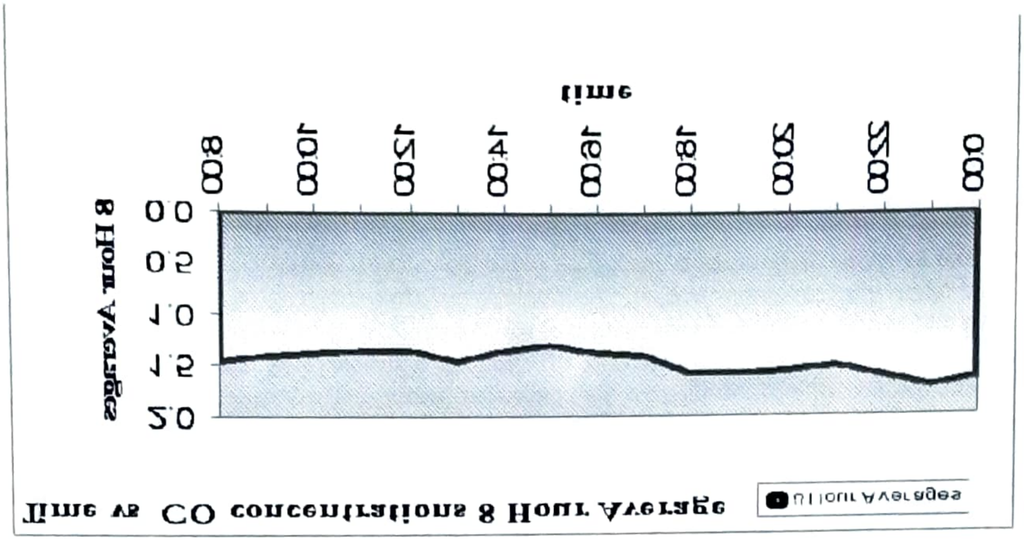

Figure 2 Variation of CO 8 Hr averages with Time

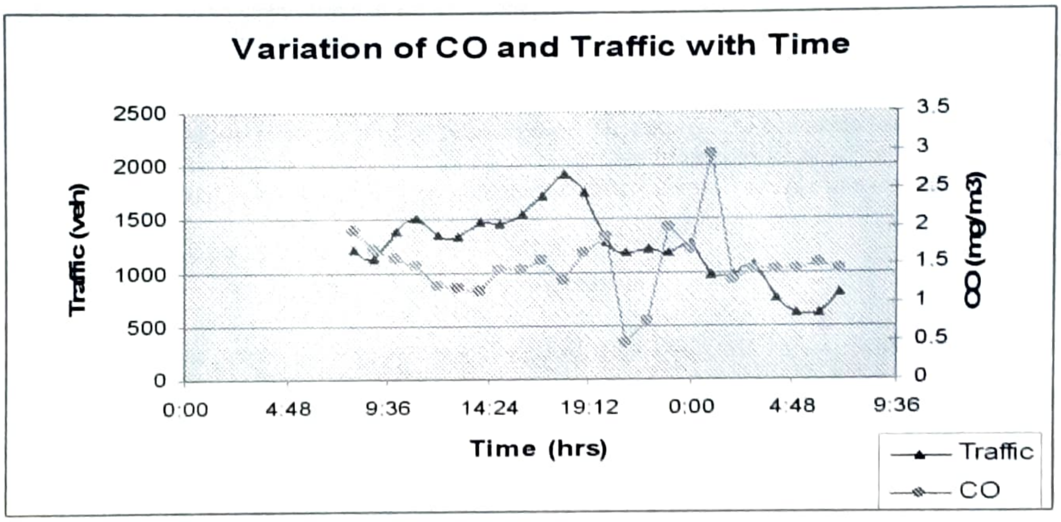

Figure 3: Variation of CO with Traffic Volume

3.0 REGRESSION ANALYSIS

Multiple linear regression analysis was carried out to identify the influence of both traffic and meteorological parameters on ambient CO levels. Values of all the variables represent one-hour averages. Since, the data was collected at single site for duration of 24 hours, there exists 24 data sets. Different models developed with set of explanatory variables are presented in Table 3.

Table 3: Results of Multiple Linear Regression Analysis

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Wind Speed	-0.5698 (-1.502)	-0.09153 (-0.429)	-0.333 (-1.362)	*	-0.1162 (-0.643)	*	*
Traffic	0.000357 (0.82)	-0.000078 (-0.233)	*	-0.00014 (-0.479)	*	-0.00015 (-0.525)	*
Temperature	0.0423 (1.503)	*	0.027 (1.29)	0.0069 (0.436)	*	*	0.0075 (0.484)
Intercept	0.611	1.0646	1.199	1.549	1.562	1.684	1.3654
R^2 Value	0.121	0.029	0.09	0.021	0.018	0.0123	0.0105

All the models have been tested for

- Logical sign of each coefficient
- Student t – test value of each coefficient
- R^2 Value

As the wind speed increases, the intensity of CO will be less due to fast dispersion. Hence, sign of the coefficient should be always negative. It is observed from the Table 3 that CO coefficient is negative in all the models as expected. Similarly, with higher atmospheric temperature, CO will be dispersed quickly, which should be reflected with negative coefficient in the models. Unfortunately, in all the seven models developed, negative temperature coefficient was obtained. Higher traffic intensity yield higher CO concentration in ambient air. If the traffic coefficient is positive, then it is logical. Except in Model 1, the sign of traffic coefficient in all models is illogical. The student t value of all the coefficients in all the seven models are less than the table values, indicating their insignificant contribution in explaining CO variation in ambient air. Incidentally, the R^2 values obtained for all models are close to 0, which indicates poor fit. These models have less explanatory power. This may be attributed to single site data and small sample size.

4.0 CONCLUSIONS

One-hour average CO concentrations are fluctuating over the period of the day, however the 8-Hour average CO concentrations are more are less constant over the day as shown in Figure 2. The CO levels observed in the study area are within the stipulated limits, as prescribed by Central Pollution Control Board, India. The maximum 8 Hr average intensity of CO is found to be 1.72 mg/m^3. From the analysis it is seen that there exists no direct relation between the 1 Hr average CO concentrations and the traffic volume. Probably, this may be attributed to 24 data sets obtained from same location. Further, other traffic parameters like modal share, speeds, etc may contribute in enhancing model explanatory power.

Acknowledgements

The data used in the present study was provided by CRRI, New Delhi. Mr. M.V.L. Satish had undergone his industrial training at CRRI, New Delhi under the guidance of Ms Anuradha Shukla, Scientist and group leader, ERTS division. The authors are grateful to Ms Anuradha Shukla and CRRI for encouraging them to publish this work.

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