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Temporal Variation of Carbon Monoxide Concentration at Congested Urban Roadways Intersection

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ABSTRACT

The carbon monoxide (CO) is dominant among major traffic emitted pollutants such as respirable suspended particulate matter (RSPM), oxides of nitrogen (NOx), volatile organic carbons(VOCs) and ozone (O_3) etc. It is generated by automobiles due to incomplete combustion of the fuel. The vehicles that queue up at an intersection spend more time in idle driving mode generating more pollutant leading to higher pollutant concentrations. Therefore, the trends of average hourly CO concentrations at various locations of congested roadways intersection have been investigated. The four approach roads making intersection have been selected for the present study. CO monitoring has been carried out at 2 selected locations of each approach road. The CO concentration has been monitored from 8:00 AM to 8:00 PM at each location using portable online CO monitor. The average hourly CO concentrations data have been analyzed using MS excel spread sheet for each approach road. The average hourly concentration of monitored CO concentration at all receptors locations shows two peak CO concentration values (i.e., the morning peak and evening peak) throughout the monitoring programme (March to May, 2011). The comparison of monitored values of average 1 hourly CO concentration levels as well as 8 hourly average concentration levels of CO showed non compliance with the prescribed standards (4000 $\mu g/m^3$ average hourly and 2000 $\mu g/m^3$ average 8 hourly CO concentration). The temporal CO concentration at various approach roads making roadway intersection shows non-uniform. The highest CO concentration has been observed to be towards high rise building and vice-versa. The least CO concentration has been observed towards either low rise building or open area.

***Keywords**:* Carbon monoxide, Monitoring, Road intersection, Temporal variation

I. INTRODUCTION

The improvements in vehicle technology play a significant role in reducing traffic emissions at the source, air pollution abatement will remain a challenge. Increasing demand for transportations due to economic growth has triggered a boom in the number and use of motor vehicles in India. Motor vehicles are emerging as the largest source of urban air pollution and are responsible for about 70% of the air pollution loads in most of the Indian cities. CO is the dominant among major traffic emitted pollutants such as respirable suspended particulate matter (RSPM), oxides of nitrogen (NOx), volatile organic carbons(VOCs) and ozone (O_3) etc. The CO is a colorless, odorless, poisonous air pollutant. At high concentrations, CO reduces the amount of oxygen in the blood, causing heart difficulties in people with chronic diseases, reduced lung capacity and impaired mental abilities. Chronic exposure to relatively low levels of CO may cause persistent headaches, lightheadedness, depression, confusion, memory loss, nausea and vomiting [1]. It is unknown whether low-level chronic exposure may cause permanent neurological damage [2]. Typically, upon removal from exposure to CO, symptoms usually resolve themselves, unless there has been an episode of severe acute poisoning [1]. Chronic CO exposure might increase the risk of developing atherosclerosis [3, 4]. Long-term exposures to CO present the greatest risk to persons with coronary heart disease and in females who are pregnant [5]. Urban road traffic has been identified as a major source of air pollution in urban areas [6] with subsequent adverse human health effects [7, 8, 9]. Motor vehicles make significant contribution to the atmospheric pollution inventory; that contributed over 90% of CO emission in the urban area [10]. The CO levels have always been the target of investigation in most monitoring and modeling studies concerning vehicular pollution near roadways and major intersections in many cities [11, 12, 13]. CO is produced due to incomplete fuel combustion that characterize mobile as opposed to stationary pollution sources and therefore it can be used as an indicator for the contribution of traffic to air pollution [14]. Air quality monitoring studies have measured elevated concentrations of pollutants emitted directly by motor vehicles near large roadways relative to overall urban background concentrations although these studies have been for short durations [15, 16, 17, 18, 19]. These elevated concentrations generally occur within a few hundred meters of the road; however, this distance may vary depending on the traffic patterns, environmental conditions, topography, and the presence of roadside structures [20]. This paper presents average hourly CO concentration variations at various locations of congested urban roadway intersection.

II. MATERIALS AND METHOD

This section describes the methodology adopted in the present study. It includes site selection, reconnaissance survey, receptor locations on each approaching roads and CO concentration monitoring technique CO along with data analysis. The detail description has been given in subsequent sections.

2.1 Site Selection

The approaching roads of ITO intersection (Latitude:30^0 $29^/$ $35^{//}$ N & Longitude: 28^0 $25^/$ $56^{//}$ E) have been selected for the monitoring of CO concentration. The intersection having typical traffic flow characteristics and natural ventilation conditions is fully signalized. The approach roads include:

- Towards Laxmi Nagar (Surrounded by Police Headquarters and Institution of Engineers)

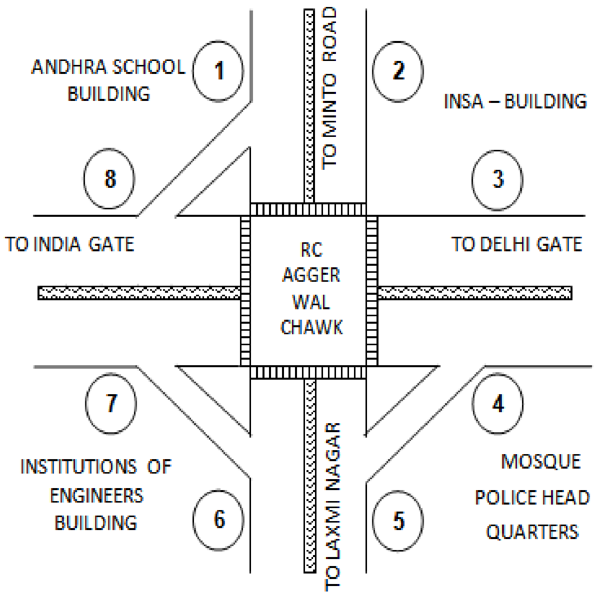

Fig. 1: Typical layout of an ITO intersection with various approach roads (not in scale)

- Towards Minto Road (Surrounded by INSA Building and Andhra School Building)
- Towards Delhi Gate (Surrounded by INSA Building and Mosque, Police Headquarters)
- Towards India Gate (Surrounded by Andhra School Building and Institution of Engineers)

At each approach road 2 locations have been selected (Fig. 1) and CO concentration has been monitored from 8:00 AM to 8:00 PM at each location (Table – 1).

Table -1: Description of sampling locations

Location No.	Description of locations
1	Andhra School Building side, towards Minto Road
2	INSA Building side, towards Minto Road
3	INSA Building side, towards Delhi Gate
4	Police Headquarters Building side, towards Delhi Gate
5	Police Headquarters Building side, towards Laxminagar
6	Institution of Engineers Building side, towards towards Laxminagar
7	Institution of Engineers Building side, towards India Gate
8	Andhra School Building side, towards India Gate

2.2 Reconnaissance Survey

The site characteristics in terms of approaching roads, their width, median and number of lanes have been measured. The meteorological data – wind speed, wind direction, atmospheric stability, mixing height etc., has been collected from Indian Meteorological Department. The traffic volume along with their categories has been collected from the site during monitoring period. The traffic volume comprised of: heavy commercial vehicles (Bus/Trucks), light vehicles, cars, three wheelers (M3W) and two wheelers (M2W). The numbers of vehicles have been counted at an hourly basis for all the categories. Traffic counts have also been taken from 08:00 hrs 10:00 hrs (morning peak traffic volume), 12:00 hrs to 13:00 hrs (Afternoon peak traffic volume) and 18:00 hrs to 20:00 hrs (Evening peak traffic volume) during course of study. The data of traffic volume and composition have been cross verified from the data collected by TRIP, IIT Delhi.

2.3 CO Monitoring and Data Analysis

CO monitoring at 8 locations of ITO intersection has been carried out using portable online CO monitor since March 3, 2011 to May 4, 2011. The monitoring has been continued for three consecutive days to get the representative data of CO concentration. The Instrument has been pre-calibrated and having least count of 0.1 ppm. Since, the instrument did not have data acquisition system/storage system, the data have been manually recorded at 3 minute intervals. The average of 20 readings of each hour gives the average hourly concentration of CO. The CO concentration has been monitored from 8:00 AM to 8:00 PM at each location of each approaching road continuously for 3 days in a month. The average hourly CO concentrations data have been analyzed using MS excel spread sheet to obtain the CO concentration trends at each approach road.

III. RESULTS AND DISCUSSION

The hourly concentration of monitored CO concentration at all receptors locations clearly shows the morning peak (9:00 AM to 11:00 AM with highest CO level at 10:00 AM) and evening peak (6:00 PM to 8:00 PM with highest CO level at 7:00 PM). This trend has been observed in all the days of monitoring in the month of March, April and May, 2011 with some variations in values at all locations of various approach roads forming intersection. This may be due to occurrence of maximum traffic, their emissions and dispersive behavior causing built-up of CO concentration in the microenvironment. The comparison of monitored average hourly CO concentration levels showed non compliance with the prescribed standards (4000 µg/m^3 average hourly CO concentration and 2000 µg/m^3 average 8 hourly CO concentration).

3.1 Temporal CO Concentration Variation at Minto Road

Fig. 2 shows the temporal CO concentration variation on approach road towards Minto Road,

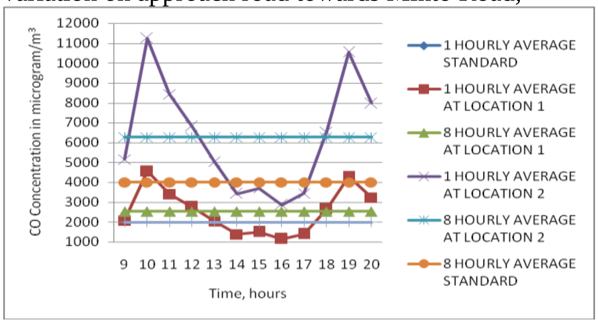

Fig. 2: CO concentration distribution at either side of the road towards Minto Road

which is surrounded by INSA Building at one side and Andhra School Building at other side. The 1 hourly average concentration of CO has been observed to be 11238 µg/m^3 at morning peak (9:00 to 10:00 AM) at location 2, which is situated towards INSA Building. However, at evening peak (6:00 to 7:00 PM) 1 hourly average concentration of CO has been observed to be 10554 µg/m^3. In both the traffic peak hours, 1 hourly average CO level has been violated the prescribed standard (4000 µg/m^3). At location 1, i.e., towards Andhra School Building side, the 1 hourly average concentration of CO has been found to be 4550 µg/m^3 at morning peak (9:00 to 10:00 AM) and 4271 µg/m^3 at evening peak (6:00 to 7:00 PM). In both the traffic peak hours, 1 hourly average CO level has been violated the prescribed standard (4000 µg/m^3). The occurrence of higher CO levels may be due to emissions caused by maximum traffic on the approaching road and trapping of CO in the vicinity. In fact, the INSA Building is higher than the Andhra School Building at other side making step down type short street canyon. When wind flow direction approaches from INSA Building to Andhra School Building, the skimming flow towards INSA Building takes place, which may cause shifting of CO. The monitored results show non-compliance of 8 hourly average CO levels at location 2, however, at location 1, it has been found to be marginally above the permissible level.

3.2 Temporal CO Concentration Variation at Delhi Gate

Fig. 3 shows the 1 hourly average CO concentration levels at location 3 and location 4 on approaching road towards Delhi Gate. The 1 hourly average CO concentration level has been observed to be 10649 µg/m^3 at morning peak (9:00 to 10:00 AM) at location 2, which is situated towards INSA Building. However, at evening peak (6:00 to 7:00 PM) 1 hourly average concentration of CO has been observed to be 9817 µg/m^3. The 1 hourly average CO levels violated the prescribed permissible standard of 4000 µg/m^3. At location 4, i.e., towards Police Headquarters Building side, the 1 hourly average concentration of CO has been found to be 5490 µg/m^3 at morning peak (9:00 to 10:00 AM) and 5157 µg/m^3 at evening peak (6:00 to 7:00 PM). Here also, 1 hourly average CO level has been has been observed to be above the prescribed permissible standard (4000 µg/m^3). This occurrence of higher CO levels may be due reason described in section 3.1. Furthermore, the 8 hourly average CO levels at location 3 and location 4 have been found to be quite above the permissible level.

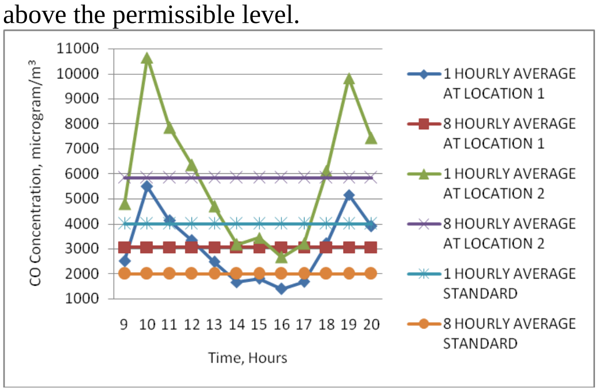

Fig. 3: CO concentration distribution at either side of the road towards Delhi Gate

3.3 Temporal CO Concentration Variation at Laxmi Nagar

The trend of temporal variation of 1 hourly average CO concentration levels at location 5 and location 6 on approaching road towards Laxmi Nagar has been shown in Fig. 4. The 1 hourly average CO concentration level has been found to be 6619 µg/m^3 at morning peak (9:00 to 10:00 AM) at location 5, which is situated towards Police Headquarters Building. However, at evening peak (6:00 to 7:00 PM) 1 hourly average concentration of CO has been

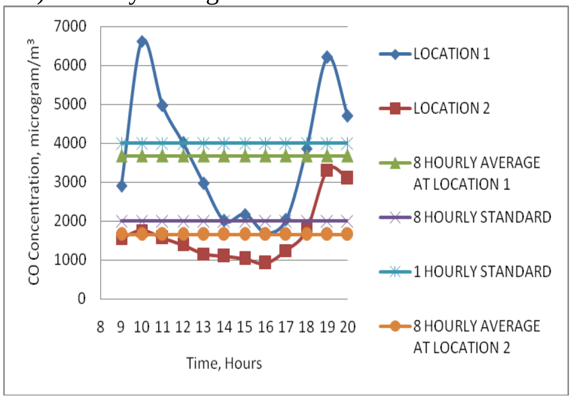

Fig. 4: CO concentration distribution at either side of the road towards Laxmi Nagar

observed to be 6213 µg/m^3. The 1 hourly average CO levels violated the prescribed permissible standard of 4000 µg/m^3. At location 6, i.e., towards Institution of Engineers Building, the 1 hourly average concentration of CO has been found to be 1756 µg/m^3 at morning peak (9:00 to 10:00 AM) and 3309 µg/m^3 at evening peak (6:00 to 7:00 PM). The 1 hourly average CO level has been has been observed to be below the prescribed permissible standard (4000 µg/m^3). This occurrence of lower CO levels may be due to proper ventilation causing more dispersion resulting dilution of CO levels. Furthermore, the 8 hourly average CO levels at location 5 (3678 µg/m^3) has been found to be quite above the permissible standard (2000), however, at location 6 (1657 µg/m^3), it has been found to be below the permissible level.

3.4 Temporal CO Concentration Variation at India Gate

Fig. 5 shows the temporal variation of 1 hourly average CO concentration levels on approach road towards India Gate, which is surrounded by the Andhra School Building at one side and the Institution of Engineers building at other side. The 1 hourly average concentration of CO has been observed to be quite higher, 9604 µg/m^3 (9:00 to 10:00 AM) and 7195 µg/m^3 at evening peak (7:00 to 8:00 PM) towards Institution of Engineers Building side (location 7). At location 8, i.e., towards Andhra School Building side, the 1 hourly average concentration of CO has been found to be 3938 µg/m^3 at morning peak (9:00 to 10:00 AM) and 4216 µg/m^3 at evening peak (6:00 to 7:00 PM). In both the traffic peak hours, 1 hourly average CO level has been violated the prescribed permissible standard of 4000 µg/m^3. The monitored results show non-compliance of 8 hourly average CO levels at location 7 (5149 µg/m^3) and location 8 (2457 µg/m^3), however, at location 8, it has been found to be marginally above the permissible level. In fact, the Andhra School Building and the Institution of Engineers building both have almost equal levels and far away providing proper ventilation to the road.

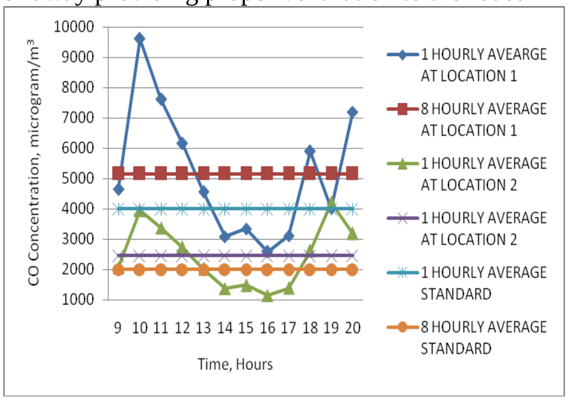

Fig. 5: CO concentration distribution at either side of the road towards India Gate

IV. CONCLUSIONS

The average hourly concentration of monitored CO concentration at all receptors locations shows two peak CO concentration values (i.e., the morning peak and evening peak) throughout the monitoring programme (March to May, 2011). The comparison of monitored values of average 1 hourly CO concentration levels as well as 8 hourly average concentration levels of CO showed non compliance with the prescribed standards (4000 µg/m^3 average hourly and 2000 µg/m^3 average 8 hourly CO concentration). The temporal CO concentration at various approach roads making roadway intersection shows non-uniform. The highest CO concentration has been observed to be towards high rise building and vice-versa. The least CO concentration has been observed towards either low rise building or open area. This may be due to faster dispersion of CO causing dilution. The CO concentration variability at various approaches roads concluded the shifting and built up of pollutant towards high rise building irrespective of traffic volume.

V. ACKNOWLEDGEMENT

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