Ambient air quality studies on Cuddalore
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ABSTRACT
During the summer of 2009, concentrations of oxides of nitrogen (NO\textsubscript{x}), oxides of sulphur (SO\textsubscript{x}), suspended particulate matter (SPM) and carbon monoxide (CO) were collected over successive periods of about 8 hour at eight sites. High volume air sampler was used to measure the concentration of Oxides of nitrogen (NO\textsubscript{x}), Oxides of sulphur (SO\textsubscript{x}), suspended particulate matter (SPM) and battery operated portable CO monitor was used to measure the concentration of carbon monoxide (CO). The results reported pertain to an eight hour successive preliminary air sampling exercise carried out at each of the eight select locations in Cuddalore, a southern semi urban settlement in India. Criteria pollutants SPM, CO, SO\textsubscript{2} and NO\textsubscript{2} measured are found to have either crossed or on the average of crossing the limits, necessitating the immediate installation of a continuous monitoring and control mechanism. While transport related emissions are the major sources of air contamination, increasing civil construction activities also contribute to particulates. The exponential rise in volume of vehicles, disadvantageous traffic flow pattern, differing driving cycle pattern and human interceptions deserve due attention. The concentrations of SO\textsubscript{2} values were exceeded the National Ambient Air Quality Standard (NAAQS) at three locations. The SPM values were exceeded the National Ambient Air Quality Standard (NAAQS) at all the eight locations. The NO\textsubscript{2} values were exceeded the National Ambient Air Quality Standard (NAAQS) at all the eight locations. The CO values were exceeded the National Ambient Air Quality Standard (NAAQS) at seven locations.

Keywords: Semi urban air sampling, transport emissions, ambient air quality, criteria pollutant, preliminary assessment.

1. Introduction
Developed and developing economy and globalization have resulted in migration of fast changing energy intensive life style, mechanization and automation as a consequence of scientific advances including those of newer branches of science. Polluted air, polluted space, polluted land and polluted water are the resulting undesired byproducts. Awareness of air contamination and measures to monitor and control air quality are inadequate considering the rapidity of increase in pollution levels. Pragmatic ill effects on human health and difficulty in treating air warrant due attention to continuously assess, monitor and control the ambient air quality, air being a primary source of lives. Air pollution harms every living being, more so the human population and in particular target severely the occupational groups like car drivers, traffic police personnel, parking lot attendants, tunnel workers, road side vendors, owners and employees of uncovered or frequently open commercial establishments in traffic dense and narrow locations, and all users of public places like bus stands, workshops and cinema theaters. The ill effects on health are severe with the fetus, children, elders and cardiovascular and angina pectoris patients. Population concentration within the confined
urban area, traffic congestion due to limited road space, traffic queuing at the signals, high traffic density in two way roads, and forced stop-go driving cause poor air quality and aggravate related health care issues. Pollutant concentrations, proximity, nature and duration of exposure, are factors deciding the level of harms. About 60 percent of air pollution in Indian cities is due to automobile exhaust emission. The vehicular emission contains more than 450 different organic chemical compounds either in gaseous or in particulate or in the combined forms. The emission loads in Indian urban cities are in the range of thousands of tons per day. The gains achieved through reduced standalone vehicle emissions are offset by the rapid rise in volume of vehicles. Internal combustion engines, the prime movers for automobiles emit carbon monoxide, hydrocarbons, oxides of nitrogen, lead, road and tyre dust, carbon particles, and aldehydes. Some of these compounds react in sunlight to produce secondary, genotoxic, cytotoxic, fibrogenic, and carcinogenic compounds like benzene, the class “A” human carcinogen. Transport sector particularly gasoline combustion has a significant role in benzene emission. Carbon monoxide causes dizziness, headache, fatigue, and impaired judgment. It affects the functioning of brain and heart. At higher concentration the impact is fatal. Particulate matter causes respiratory disorder, asthma, reduced atmosphere visibility and cancer. It affects lungs and tissues. Oxides of nitrogen cause lung irritation, bronchitis, pneumonia, asthma, respiratory infections, pulmonary edema, and emphysema. Sulfur dioxide affects human lungs, and respiratory system. It causes sulfurous smog, acid rain and reduced atmosphere visibility. Particulate matter combined with sulphur oxides is more detrimental than either of them separately. Ground level ozone in photochemical smog (smog is the product of reaction of CO, NOx and HC with each other in the presence of sunlight) causes chest constriction and irritation of the mucous membrane infection.

2. Experimental Procedure

2.1. The study area

Cuddalore is an ancient southern town in the state of Tamilnadu, India. Popularity known as temple for salivates (a major sect of Hindus), it is the headquarters for them and believed to be the heart for the world. Cuddalore District is predominately an agricultural district with coastal line stretching from Pondicherry Union Territory in the North to the mouth of the River Coleroon in the South. The total geographical area covered by the district is 4283 sq. km with coastal line of 68 kms. The district is bounded on the north by VIluppuram District, on the east by the Bay of Bengal, on the south by Nagapattinam District, and on the west by Perambalur District. Annamalai University, a residential unitary seat of higher learning adjoining Chidambaram has more than 75 years of standing with variety of faculties. Population of Cuddalore town is around a 22, 80,530 excluding that of tens of existing and upcoming mini satellite townships surrounding.

2.2. Description of sampling sites

Eight sites were selected for Ambient Air Quality (AAQ) monitoring in Cuddalore. The selected sites were places of maximum population, heavy traffic, and commercial areas. A random selection sampling has been carried out at all the sites. Table 1 shows the location, monitoring period and classification of site for SPM, NOx, SOx and CO in the Cuddalore region. Geographical locations of the sampling sites were measured from the meteorological department, Chidambaram.

2.2.1. Periyakaraikadu (E1)
This site possesses one way traffic system, heavy traffic flow, stop-go opportunity and railway over bridge construction activities. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 44, 20, 21 and 15 respectively.

2.2.2. Sangolikuppam (E2)

This site has one way traffic system, heavy non-smooth vehicle flow, narrow sharp turn, shopping complex, and parking lots. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles/ heavy vehicles were 46, 18, 22 and 14 respectively.

2.2.3. Kumarakudi (E3)

This site has one way traffic system, vehicle queuing, stop-go practice, open-loop signal control, and high vehicle mobility. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles/ heavy vehicles were 43, 18, 22 and 17 respectively.

2.2.4. Cuddalore old town (E4)

This site has two way traffic signal, Vehicle queuing and heavy traffic flow. Large number of bus operations, queuing, frequent stop-go and repeated driving cycles. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles/ heavy vehicles were 44, 18, 23 and 15 respectively.

2.2.5. Semmandalam (E5)

This site has one way traffic system, less frequent queuing, less stop-go practice, and commercial bazaar activity. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 41, 18, 26 and 15 respectively.

2.2.6. Alapakkam (E6)

This site encountered gate closures, heavy traffic flow, stop-go opportunity and railway over bridge construction activities. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 43, 21, 22 and 14 respectively.

2.2.7. Gundusalai (E7)

This site has one way traffic signal, vehicle queuing and narrow sharp turn. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 43, 35, 10 and 12 respectively.

2.2.8. Cuddalore bus stand (E8)

This site faces large number of bus operations, vehicle queuing, frequent stop-go operation, idling, acceleration, cruising, deceleration, and non-smooth vehicle flow. Percentage traffic shares of two wheelers / three wheelers / light vehicles / heavy vehicles were 2, 0, 0 and 98 respectively.
Table 1: Details of air quality monitoring station in Cuddalore, India

| Site             | Code | Site classification | Monitoring period (10.00 to 06.00) |
|------------------|------|---------------------|-----------------------------------|
| Periya Karaikadu | E₁   | Traffic area        | 05-01-2009 to 07-01-2009           |
| Sangolikuppam    | E₂   | Traffic area        | 08-01-2009 to 10-01-2009           |
| Kumarakudi       | E₃   | Traffic area        | 11-01-2009 to 13-01-2009           |
| Cuddalore Old Town| E₄   | Traffic area        | 14-01-2009 to 16-01-2009           |
| Semmandalam      | E₅   | Traffic area        | 17-01-2009 to 19-01-2009           |
| Alappakkam       | E₆   | Traffic area        | 20-01-2009 to 22-01-2009           |
| Gundusalai       | E₇   | Traffic area        | 23-01-2009 to 25-01-2009           |
| Bus stand        | E₈   | Traffic area        | 26-01-2009 to 28-01-2009           |

3. Materials and Method

SPM (suspended particulate matter) concentrations were measured by finding the sample air volume (m³) through an orifice meter and the mass (µg) of particulate matter collected in a Watt man grade 1 fibreglass filter paper. Concentrations of SO₂ and NO₂ (µg / m³ or PPM) were colorimetrically determined using a spectrophotometer. 5 to 20 ml of reagent (sodium tetra chloromercurate for West and Geake method to find SO₂ and sodium hydroxide for NO₂) filled in a train of impingers of the high volume sampler trap specific contaminant in air. Air flows to the impingers were determined using rotameters. Instantaneous carbon monoxide concentrations were directly recorded using a battery operated portable CO monitor (CO 84 ENDEE make).

3.1 Suspended Particulate Matter

High volume air sampler was used for the monitoring of particulates. Before sampling, the watt man filter GFA (20.3cm x25.4cm) of the high volume sampler was kept at 15-34 °C, 50% relative humidity for 24-hour and then weighed. The filter paper was placed into the filter holder of the high volume sampler and air was drawn through a 410 cm² portion of the filter at the flow rate of 1.70 m³/min. The filter was removed after sampling. The mass concentration of suspended particulates in ambient air, expressed in micrograms per cubic meter, was calculated by measuring the mass of particulates collected and the volume of air sampled.

3.2 Nitrogen oxides

Ambient air was continuously drawn into 35ml of sodium hydroxide solution at a flow rate of 2 LPM for 8 hour and Jacobs and Hochhesier method in the laboratory estimated it. Sodium hydroxide solution forms a stable solution of sodium nitrite. The nitrite ion produced during sampling was determined colorimetrically by reacting the exposed absorbing reagent with phosphoric acid, sulphanilamide and N-(1-naphthyl ethylene-diamine dihydrochloride producing an azo dye. The absorbance of the colour was read at 540 nm. The range of the analysis was between 0.01 and 1.5 µg/ml.

3.3 Sulphur oxides

Ambient air was continuously drawn into 35ml of sodium tetrachloromercurate solution at a flow rate of 1.5 LPM for 8 hour and Sodium tetrachloromercurate method in the laboratory
estimated it. Samples for SO$_2$ are collected using high volume sampler in the impinger containing the absorbing reagent, sodium tetrachloromercurate. After collecting the gas in the absorbent, proper volumes and concentrations of sulphamic acid, formaldehyde, and pararosaniline reagent are added to develop the red-purple colour. The intensity of the colour is measured after half an hour by taking optical density at the wavelength of 560 nm.

4. Results and Discussion

Figures 1&2 and Table 2 illustrate the eight hour contaminant levels at the sampled sites along with standard limits for comparison. SPM levels have exceeded limits at all the eight sample sites. CO level has crossed the limit at seven of the eight sample sites. SO$_2$ level has crossed the limit at three of the eight sample sites. NO$_X$ level has crossed the limit at all the eight sample sites. It is likely that the alarming levels of all the pollutants will be revealed if a continuous monitoring is carried out, in the place of random sampling.

Figure 1: Ambient air quality in cuddalore

Figure 2: Ambient air quality in cuddalore
Table 2: Result Tabulation

| Location            | SPM (200µg/m³) | NOx (80µg/m³) | SOx (80µg/m³) | CO mg/m³ |
|---------------------|----------------|---------------|---------------|----------|
| Periya karaikadu (E₁) | 376.52         | 125.18        | 99.89         | 0-2.4    |
| Sangolikuppam (E₂)  | 260.57         | 118.05        | 89.781        | 0-2.4    |
| Kumarakudi (E₃)     | 211.10         | 89.50         | 63.569        | 0-2.4    |
| Cuddalore old town (E₄) | 264.35        | 101.27        | 64.45         | 0-2.4    |
| Semmandalam (E₅)    | 241.65         | 91.77         | 76.40         | 0-2.4    |
| Alapakkam (E₆)      | 290.31         | 108.98        | 87.570        | 0-2.4    |
| Gundusalai (E₇)     | 213.67         | 89.71         | 62.920        | 0-1.2    |
| Cuddalore bus stand (E₈) | 407.41        | 115.54        | 64.909        | 0-2.4    |

Figures 3 to 10 depict the eight hour traffic shares of the two wheelers, three wheelers, light vehicles, and heavy vehicles at the sample sites during the sampling period. Except at the bus terminus, at all the other seven sites two wheelers predominantly account for nearly fifty percent and more. At the bus terminus heavy vehicles with a major share of 98 percent dominate. There is considerable correlation between pollutant levels and activities at the sites. At bus terminus with intensive transport activities two pollutants are found to cross the limits (SPM by 103.70%, and CO by 20%). NOx at the periyakaraikadu with two way traffic system is the highest (56.47% more than the limit) due to heavy automobile mobility and over bridge construction activity. NO₂ level is the second largest at the sangolikuppam. The only source for NO₂ is the auto emission, in the absence of any other industrial or commercial activities in the region. At places with one way traffic system and location specific restricted automobile mobility, the pollutant levels are observed to be relatively lower. Carbon monoxide values across the sample sites vary from zero to 2.4 mg/m³ against time. The variation is due to vehicular flow pattern, sensor proximity, and environment. The highest value recorded is 20 percent more than the standard limit 2 mg/m³.

At periyakaraikadu, having restricted automobile mobility and two-way traffic signal, the pollutant levels are: SPM (376.52µg/m³, 188.26% of the limit) crossed the standard limit.SO₂ (99.89 µg/m³, 124.86% of the limit) crossed the standard limit.NO₂ (125.18 µg/m³, 156.475% of the limit) crossed the standard limit. CO (2.4mg/m³, 120% of the limit) crossed the standard limit.

At Sangolikuppam, having restricted automobile mobility and two-way traffic signal pollutant levels are: NO₂ (118.05µg/m³, 147.56% of the limit) crossed the standard limit.SO₂ (89.789 µg/m³, 112.23% of the limit) crossed the standard limit. SPM (260.57 µg/m³, 130.285% of the limit) crossed the standard limit.CO (2.4mg/m³, 120% of the limit) crossed the standard limit. At Kumarakudi with signalized intersection, pollutant levels are: SPM (211.10µg/m³, 105.55% of the limit) crossed the standard limit.SO₂ (63.569µg/m³, 79.46% of the limit) have not crossed the standard limit. NO₂ (89.50 µg/m³, 111.87% of the limit) crossed the standard limit. CO (2.4mg/m³, 120% of the limit) crossed the standard limit.
At Cuddalore old town having restricted automobile mobility and two-way traffic signal, the pollutant levels are: SPM (264.35 µg/m³, 132.17% of the limit) crossed the standard limit. NO₂ (101.27 µg/m³, 126.58% of the limit) crossed the standard limit. SO₂ (64.45 µg/m³, 80.56% of the limit) have not crossed the standard limit. CO (2.4 mg/m³, 120% of the limit) crossed the standard limit.

At Semmandalam having restricted automobile mobility and two-way traffic signal, the pollutant levels are: SPM (241.65 µg/m³, 120.82% of the limit) crossed the standard limits. NO₂ (91.77 µg/m³, 114.71% of the limit) crossed the standard limits. SO₂ (76.40 µg/m³, 95.50% of the limit) have not crossed the standard limit. CO (2.4 mg/m³, 120% of the limit) crossed the standard limit.

At Alapakkam with two-way traffic signal pollutant levels are: SPM (290.31 µg/m³, 145.15% of the limit) crossed the standard limits. NO₂ (108.98 µg/m³, 136.22% of the limit) crossed the standard limits. SO₂ (87.570 µg/m³, 109.46% of the limit) crossed the standard limit. CO (2.4 mg/m³, 120% of the limit) crossed the standard limit.

At Gundusailai having restricted automobile mobility with two-way traffic signal pollutant levels are: SPM (213.67 µg/m³, 106.83% of the limit) crossed the standard limits. NO₂ (89.71 µg/m³, 112.13% of the limit) crossed the standard limits. SO₂ (62.920 µg/m³, 78.65% of the limit) have not crossed the standard limit. CO (1.2 mg/m³, 60% of the limit) have not crossed the standard limit. At the Cuddalore bus terminus with intense heavy vehicle mobility pollutant levels are: SPM (407.41 µg/m³, 203.70% of the limit) crossed the standard limit. NO₂ (115.54 µg/m³, 144.42% of the limit) crossed the standard limit. SO₂ (64.909 µg/m³, 81.13% of the limit) have not crossed the standard limit. CO (2.4 mg/m³, 120% of the limit) crossed the standard limit.

4.1 Over all ranges of pollutant levels at Chidambaram town

The range of pollutant levels as per the preliminary random investigation carried out at 8 select locations in Cuddalore, Indian towns are summarized here under.

| Pollutant | Range (µg/m³) | Standard limit (µg/m³) |
|-----------|--------------|------------------------|
| SPM       | 211.10 to 407.41 | 200                    |
| NOₓ       | 89.50 to 125.18  | 80                     |
| SOₓ       | 62.920 to 99.89  | 80                     |
| CO        | 0 to 2.4 (mg/m³) | 2 mg/m³                |

The results of the investigations on ambient air quality in Cuddalore are on the anticipated lines, making a clear case warranting immediate installation of a "continuous ambient air quality monitoring process" on stream.
### Table 4: Result Tabulation (cont...)

| Locations                  | Details and Activities                                                                 | Pie Chart details | Legend | %     | no of vehicles |
|----------------------------|----------------------------------------------------------------------------------------|-------------------|--------|--------|-----------------|
| Periyakaraikud (E₁)        | Two way, less queuing, less stop-go and Industrial complex and Bridge construction     | ![Figure 3:](image) |        |        |                 |
| Sangolikuppam (E₂)         | Two way, heavy non-smooth flow, Narrow sharp turn, Industrial complex and Parking lots. | ![Figure 4:](image) |        |        |                 |
| Kumarakudi (E₃)            | Two way, queuing, stop-go, Open loop traffic signal and vehicle mobility.               | ![Figure 5:](image) |        |        |                 |
| Cuddalore old town (E₄)    | Large number of bus operations, queuing, frequent stop-go and repeated driving cycles. |                   |        |        |                 |

**Legend**

1. 44.00  5545
2. 20.00  2466
3. 21.00  2567
4. 15.00  1896
### Locations

| Locations       | Details and Activities                                                                 | Pie Chart details                                      | Legend | %     | no of vehicles |
|-----------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------|--------|--------|----------------|
| Semmandalam ($E_2$) | Two way, less queuing, less stop-go, Commercial bazaar                                  | ![Pie Chart](Figure 6.png)                             |        |        |                |
|                 |                                                                                       | ![Pie Chart](Figure 7.png)                             | 1      | 41.00  | 4365           |
|                 |                                                                                       |                                                         | 2      | 18.00  | 1914           |
|                 |                                                                                       |                                                         | 3      | 26.00  | 2681           |
|                 |                                                                                       |                                                         | 4      | 15.00  | 1599           |
| Alapakkam ($E_3$) | Two way, traffic signal, heavy non-smooth flow, Gate closure, Heavy traffic,Stop-go,Bridge construction | ![Pie Chart](Figure 8.png)                             |        |        |                |
|                 |                                                                                       |                                                         | 1      | 43.00  | 4906           |
|                 |                                                                                       |                                                         | 2      | 21.00  | 2400           |
|                 |                                                                                       |                                                         | 3      | 22.00  | 2431           |
|                 |                                                                                       |                                                         | 4      | 14.00  | 1625           |
| Gundusalai ($E_4$) | Two way, traffic signal Queuing, narrow sharp turn.                                     | ![Pie Chart](Figure 9.png)                             |        |        |                |
|                 |                                                                                       |                                                         | 1      | 43.00  | 4328           |
|                 |                                                                                       |                                                         | 2      | 35.00  | 3527           |
|                 |                                                                                       |                                                         | 3      | 10.00  | 1017           |
|                 |                                                                                       |                                                         | 4      | 12.00  | 1167           |
5. Conclusion

Criteria pollutant levels of SPM, NO₂ and CO in the ambient air of Cuddalore town are found to cross the limits in the single day per site random sampling, while SO₂ level is also considerable at about 124.86%(maximum). It is likely that right now the levels of all the pollutants have crossed the limits at all the sites, but not revealed due to random nature of sampling. The alarming situation will worsen further in future due to further addition of two, three and four wheelers on the road. Preliminary random studies in all pollution prone towns / cities irrespective of the grade to quantify the pollutant levels will throw light on the range of pollutant level, cause-effect correlations, trend evaluation, remedial strategies and priorities for the installation of continuous monitoring and control mechanism.

Cuddalore town is a stronger case for continuous monitoring of ambient air quality. Traffic diversions, better traffic regulation, restricting vehicles with emission features, staggering office / school timings, provision of alternate routes, by-pass infrastructures and encouraging other modes of transport are worthy considerations. Phasing out of older vehicle versions, arranging for periodic vehicle maintenance, encouraging multimode transport system and strengthening of related researches are some of the remedies. Safety measures against poor ambient air quality are to be evolved and implemented. Priority locations (like bus stand, road junction, and level crossing) and priority occupants like the drivers, traffic control personnel, and theatre employees are to be paid due to consideration and attention. Continuous monitoring shall include all the six criteria pollutants ground level ozone (O₃), Carbon monoxide (CO₂), Sulfur dioxide (SO₂), Small particulates (PM₁₀), Nitrogen dioxide (NO₂), and the lead (Pb). Additionally CO₂ and volatile organic compounds like benzene the class “A” human carcinogen also need to be quantified. Global attempts to combat air pollution need to attract the support of institutions like World Health Organization, World Bank and United Nations Organization.

Suggestions: on the basis of findings of the study, the suggestions are made: the local inhabitants, shopkeepers, pedestrians including the school children are at the health risk from ambient dust. Asphalting of the unpaved roads largely prevent re-suspension of particulates and will reduce the ambient particulate concentration. The areas with unmanaged waste
dumping, unhygienic slaughter houses have high chances of air-borne diseases and hence public sanitation and hygiene measures of these areas must be addressed to save from potential air-borne epidemics.

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6. References

1. Mehendra S.P and Krishnamurthy D (2005), Impact of introduction of one way traffic system on ambient air quality. Pollution Research, 24(1), pp 213-216.

2. Pankajam K, Harikumaran Nair R, Kesavachandran .C, Reethamma.K.Vand shashidhar (2005), Effects of automobile exhaust pollution on the pulmonary functions in shop keepers. Pollution Research, 24(1), pp 49-54.

3. Simkhada k, Murthy K, and Khanal S.N (2005), Assessment of ambient air quality in Bishnumati corridor, Kathmandu metropolis International Journal of Environmental Science and technology, 2 pp 217-222.

4. Arun Srivastava, Jain V.K (2005), A study to characterize the suspended particulate matter in an indoor environment in Delhi, India Building and Environment, pp 2046-2052.

5. Antao S.A (2004), Study of Ambient air quality of margao town in south Goa, Pollution research, 23(4), pp 741-744(2004).

6. Sharad Gokhale, Mukesh Khare (2006), Statistical behavior of carbon monoxide from vehicular exhausts in urban environments, Environmental modeling and software, 22(2007), pp 526-535.

7. Athanasios Matzoros (1990), Results from a model of Road traffic air pollution, featuring junction effects and vehicle operating models, Traffic Engineering and control, 24, p37

8. Alexopolulos, Assimacopoulos, D. and Mistsoulis, E (1993), Model for Traffic Emissions estimation, Journal of Atmospheric Environment, 27B(4), pp 435-446.

9. Hickman, A.J (1982), The estimation of air pollution concentrations from road traffic, TRRL Report, p 1052.

10. Brunekeef, B., Dockery, D.W.and Krzyzan,M.et al (1995), Epidemiologic studies on short-term effect of lowlevels of major ambient air pollution components. Environment Health Prespective., 103, suppl, 2, pp 3-13.

11. Isao Kanda,Kiyoshi Uehara, Yukio Yamao,Yasuo Yoshikawa, Tazuko Morikawa(2005), A wind-tunnel study on exhaust-gas dispersion from road
vehicles. Part II: Effect of vehicle queues. Journal of Wind Engineering and Industrial Aerodynamics, 94 (2006), pp 659–673.

12. H.K. Bandhu, Sanjiv Puri’, J.S. Shahi, D. Mehta, M.L. Garg, Nirmal Singh, P.C. Mangal, C.R. Suri, E. Swietlicki, P.N. Trehan (1996), An evaluation of the sources of air pollution in the city of Chandigarh, India: A study using EDXRF technique. Nuclear Instruments and Methods in Physics Research, B 114 (1996), pp 341-344.