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Ambient Air Quality Monitoring in Puducherry

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ABSTRACT
During the summer of 2009, concentrations of oxides of nitrogen (NO_x), oxides of sulphur (SO_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_x), oxides of sulphur (So_x), suspended particulate matter (SPM) and CO monitor was used to measure the concentration of carbon monoxide (CO). The results reported pertain to an eight hour successive continuous air sampling exercise carried out at each of the eight select locations in Puducherry, a southern semi urban settlement in India. Criteria pollutants SPM, CO, SO_2 and NO_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 SOx were below the prescribed limits. The SPM values were exceeded the National Ambient Air Quality Standard (NAAQS) at all the eight locations. The NO_x 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 - **Ambient air quality, automobile mobility, criteria pollutant, preliminary assessment, semi urban air sampling, transport emissions.**

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.

1.1 Air pollution and ambient air quality
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.

1.2 Ill effects of air pollutants on human health

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.

II. EXPERIMENTAL PROCEDURE

2.1. The study area

Puducherry, a thickly populated poorly ventilated air basin being polluted by the ever-expanding transport, construction, and commercial activities. Hence, it is necessary to forecast the impact of pollutants from the various sources located in the Puducherry for the purpose of arriving at a comprehensive air pollution scenario. Puducherry is a well known Union territory located in the southern region of India on the west coast. It was governed by the French till 1962, when it was ceded to the Indian government. Puducherry has four districts, out of which Mahe is situated on the west coast. The district of Puducherry is the best known tourist spot. There are many tourist attractions in Puducherry, and the scenic beauty of the place is equally enchanting. This would necessitate assessing the carrying capacity of the Puducherry air basin in other words fixing a limitation on the number. Population of Puducherry is around a 1.5 lakhs 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 Puducherry. The selected sites were places of maximum population, heavy traffic, and commercial areas. A continuous sampling has been carried out at all the sites. Table 1 shows the location, monitoring period and classification of site for SPM, NO_2, So_2 and CO in the Puducherry. Geographical locations of the sampling sites were measured from the meteorological department, Puducherry.

2.2.1. Indira Gandhi Signal (PDY01)

This site has two way traffic system, heavy non-smooth vehicle flow and narrow sharp turn. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 57, 9, 23 and 11 respectively. The distribution of automobile vehicles (18,591) that were plying during the sampling period at location PDY01 is depicted in a pie chart shown in fig 2.1.

2.2.2. Rajiv Gandhi Signal (PDY02)

This site has two 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 65, 11, 17 and 7 respectively. The distribution of automobile vehicles (36,153) that were plying during the sampling period at location PDY02 is depicted in a pie chart shown in fig 2.2

2.2.3. Bus stand (PDY03)

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 1, 0, 0 and 99 respectively. The distribution of automobile vehicles (2,714) that were plying during the sampling period at location PDY03 is depicted in a pie chart shown in fig 2. 3.

2.2.4. Kanniyakoil (PDY04)

This site has two 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 59, 11, 19and 11 respectively. The distribution of automobile vehicles (22,167) that were plying during the sampling period at location PDY04 is depicted in a pie chart shown in fig 2.4.

2.2.5. Nehru Street (PDY05)

This site possesses 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 70, 11, 13 and 6 respectively. The distribution of automobile vehicles (22,627) that were plying during the sampling period at location PDY05 is depicted in a pie chart shown in fig 2.5.

2.2.6. Tindivanam High Road (PDY06)

This site has two way traffic signal, heavy traffic flow, non-smooth due to narrowing and abrupt turning of roads. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 69, 10, 11 and 10 respectively. The

distribution of automobile vehicles (22,094) that were plying during the sampling period at location PDY06 is depicted in a pie chart shown in fig 2.6.

2.2.7. Cuddalore Main Road (PDY07)

This site has two way traffic signal, vehicle queuing, narrow sharp turn, heavy traffic flow, non-smooth due to narrowing and abrupt turning of roads. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 61, 11, 17 and 11 respectively. The distribution of automobile vehicles (18,649) that were plying during the sampling period at location PDY07 is depicted in a pie chart shown in fig 2.7.

2.2.8. Muruga Theatre Junction (PDY08)

This site has two way traffic signal, Vehicle queuing and heavy traffic flow. Percentage traffic shares of two wheelers/ three wheelers/ light vehicles / heavy vehicles were 71, 10, 10 and 9 respectively. The distribution of automobile vehicles (22,849) that were plying during the sampling period at location PDY08 is depicted in a pie chart shown in fig 2.8.

Table 1 Details of air quality monitoring station in Puducherry, India

Site	Code	Site classification	Monitoring (10.00a.m to06.00p.m)
Indira Gandhi Signal	PDY01	Traffic area	12-03-2009 to 03-2009
Rajiv Gandhi Signal	PDY02	Traffic area	16-03-2009 to 03-2009
Bus stand	PDY03	Traffic area	20-03-2009 to 03-2009
Kanniyakoil	PDY04	Traffic area	24-03-2009 to 03-2009
Nehru Street	PDY05	Traffic area	28-03-2009 to 03-2009
Tindivanam High Road	PDY06	Traffic area	01-04-2009 to 04-2009
Cuddalore Main Road	PDY07	Traffic area	05-04-2009 to 08-04-2009
Muruga Theatre Junction	PDY08	Traffic area	09-04-2009 to 12-04-2009

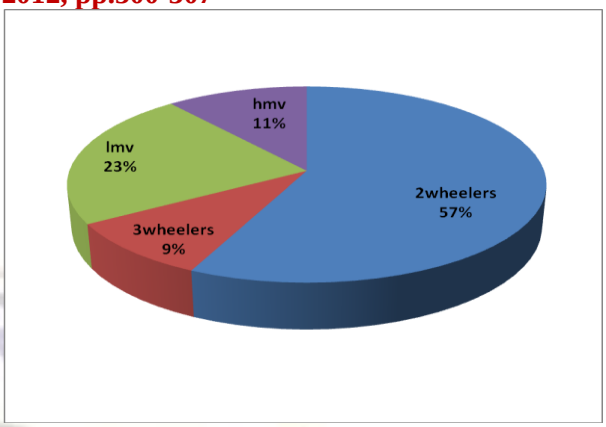

Figure 2.1 Details of vehicle plying at locationPDY01

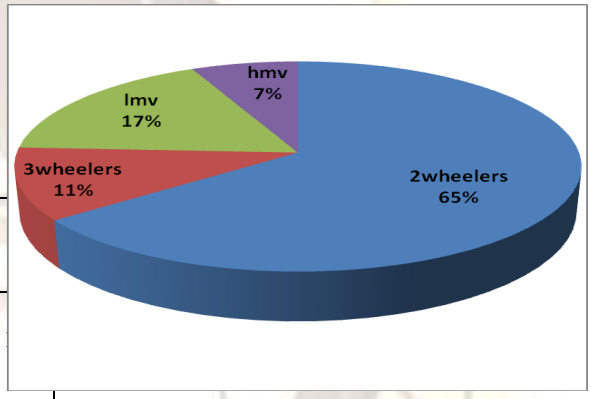

Figure 2.2 Details of vehicle plying at location PDY02

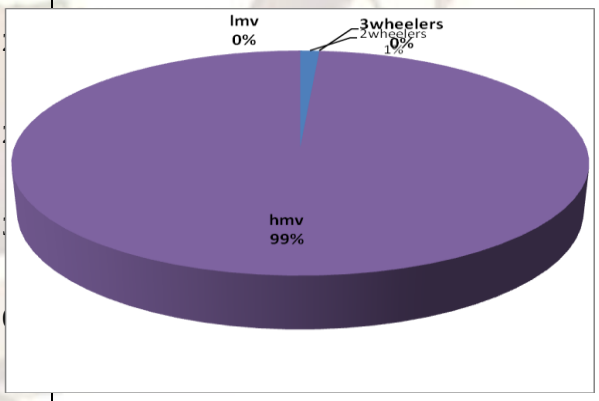

Figure 2.3 Details of vehicle plying at location PDY03

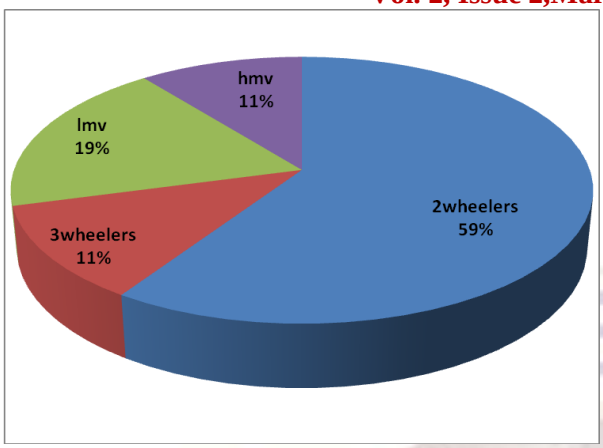

Figure 2.4 Details of vehicle plying at locationPDY04

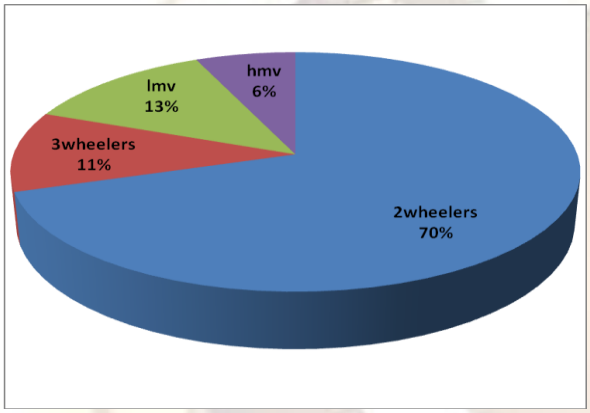

Figure 2.5 Details of vehicle plying at location PDY05

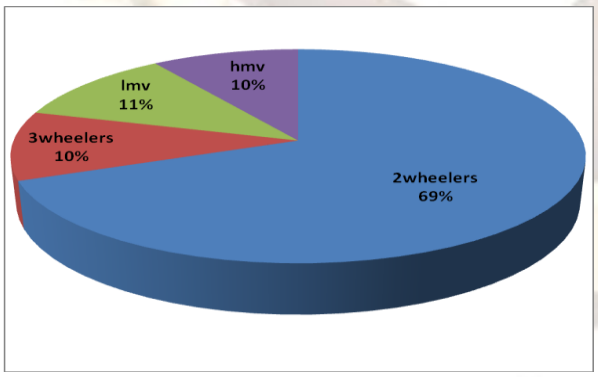

Figure 2.6 Details of vehicle plying at location PDY06

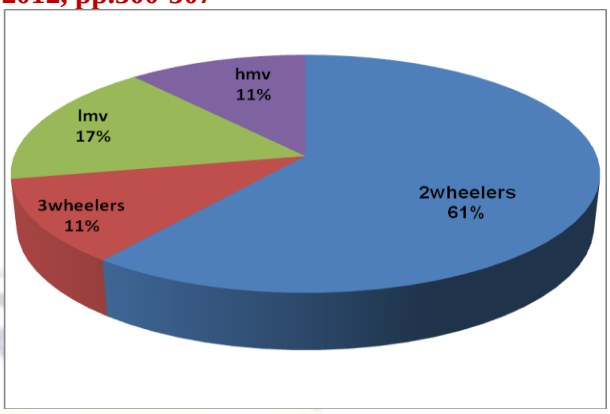

Figure 2.7 Details of vehicle plying at location PDY07

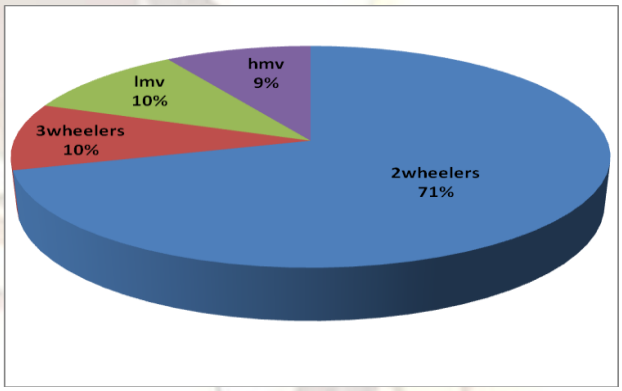

Figure2. 8 Details of vehicle plying at locationPDY08

III MATERIALS AND METHODS

SPM (suspended particulate matter) concentrations were measured by finding the sample air volume (m^3) through an orifice meter and the mass (µg) of particulate matter collected in a Watt man grade 1 fiberglass filter paper.Concentrations of SO_2 and NO_2 (µg / m^3 or PPM) were colorimetrically determined using a spectrophotometer. 5 to 20 ml of reagent (sodium tetra chloro mercurate for West and Geake method to find SO_2 and sodium hydroxide for NO_2) filled in a train of impingers of the high volume sampler trap specific contaminant in air. Air flows to the impingers were determined using rota meters. 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 wattman 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 cm^2 portion of the filter at the flow rate of 1.80 m^3/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-napthyl 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.

IV RESULTS AND DISCUSSION

Table 4.1 and Figures 4.1, 4.2, 4.3 & 4.4 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 at all the eight sites are not crossed the limits. NO_2 level has crossed the limit at all the eight sample sites. 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 99 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 94.36%, and CO by 20%). NO_2 at the rajiv Gandhi signal with two way traffic system is the highest (55.03% more than the limit) due to heavy automobile mobility.NO_2 level is the second largest at the Tindivanam main road. The only source for NO_2 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/m^3 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/m^3.

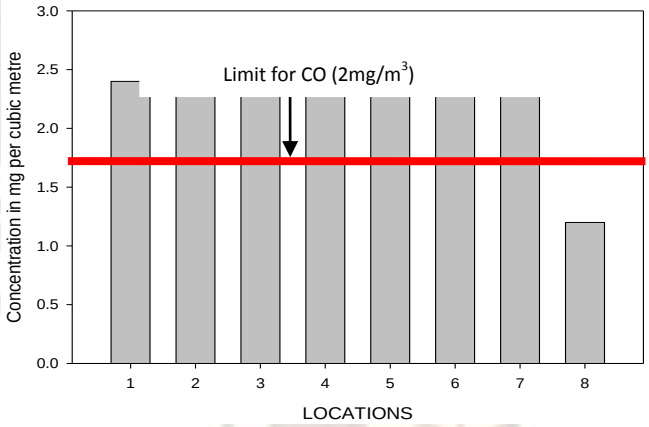

FIGURE 4.1 **CONCENTRATIONS OF CARBON MONOXIDE AGAINST EACH LOCATION**

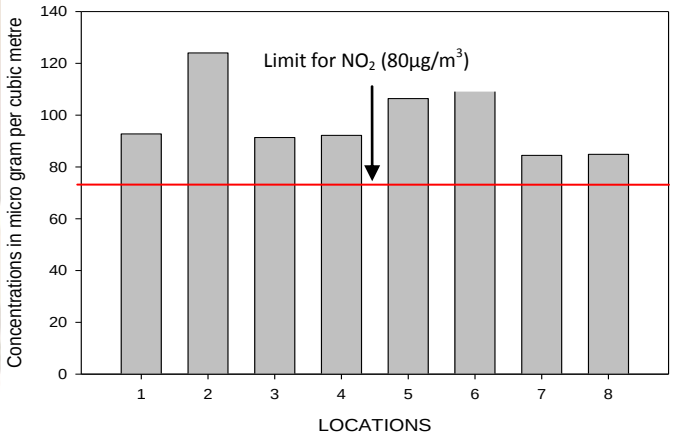

Figure 4.2 Concentrations of Nitrogen di oxide against each location

At Indira Gandhi signal, having restricted automobile mobility and two-way traffic signal, the pollutant levels are:

SPM (284.20 µg/m^3, 142.10% of the limit) crossed the standard limit. SO_2 (51.05 µg/m^3, 63.81% of the limit) have not crossed the standard limit. NO_2 (92.76 µg/m^3, 115.95% of the limit) crossed the standard limit.CO (2.4mg/m ^{3} , 120% of the limit) crossed the standard limit.

At Rajiv Gandhi signal, signalized intersection with two-way traffic signal pollutant levels are:

NO_2 (124.03µg/m^3, 155.03 % of the limit) crossed the standard limit. SO_2 (79.91 µg/m^3, 99.88% of the limit) have not crossed the standard limit.*SPM* (377.75 µg/m^3, 188.87% of the limit) crossed the standard limit.CO (2.4mg/m ^{3} , 120% of the limit) crossed the standard limit.

At the bus terminus with intense heavy vehicle mobility pollutant levels are:

NO_2 (91.35µg/m^3, 114.18% of the limit) crossed the standard limit.*SPM* (388.72µg/m^3, 194.36 % of the limit) crossed the standard limit.SO_2 (52.625µg/m^3, 65.78 % of the limit) have not crossed the standard limit.CO (2.4mg/m ^{3} , 120% of the limit) crossed the standard limit.

At kanniyakoil road with signalized intersection pollutant levels are:

SPM (297.72µg/m^3, 148.86% of the limit) crossed the standard limit.SO_2 (54.541µg/m^3, 68.17% of the limit) have not crossed the standard limit.NO_2 (92.196 µg/m^3, 115.24% of the limit) crossed the standard limit.CO (2.4mg/m ^{3} , 120% of the limit) crossed the standard limit.

At Nehru Street having restricted automobile mobility and one-way traffic signal, the pollutant levels are:

SPM (296.33µg/m ^{3}, 148.16% of the limit) crossed the standard limit. NO_2 (106.37µg/m ^{3}, 132.96% of the limit) crossed the standard limit.SO2 (64.31µg/m ^{3}, 80.38% of the limit) have not crossed the standard limit.CO (2.4mg/m ^{3} , 120% of the limit) crossed the standard limit.

At Tindivanam high road having restricted automobile mobility and two-way traffic signal, the pollutant levels are:

SPM (334.52 µg/m^3, 167.26% of the limit) crossed the standard limits.NO_2 (112.37 µg/m^3, 140.46% of the limit) have not crossed the standard limits.SO_2 (67.97µg/m^3, 84.96% of the limit) have not crossed the standard limit.CO (2.4 mg/m ^{3}, 120% of the limit) crossed the standard limit.

At Cuddalore main road with two way traffic signal pollutant levels are;

SPM (252.63 µg/m^3, 126.31% of the limit) crossed the standard limits.NO_2 (84.45 µg/m^3, 105.56% of the limit) have not crossed the standard limits.SO_2 (52.05µ/m^3, 65.06% of the limit) have not crossed the standard limit.

CO (2.4 mg/m ^{3}, 120% of the limit) crossed the standard limit.

At Muruga theatre having restricted automobile mobility and one-way traffic signal, the pollutant levels are:

SPM (258.79µg/m ^{3}, 129.39% of the limit) crossed the standard limit.

NO_2 (84.86µg/m ^{3}, 106.07% of the limit) crossed the standard limit.SO2 (44.14µg/m ^{3}, 55.17% of the limit) have not crossed the standard limit.CO (1.2mg/m ^{3} , 60% of the limit) have not crossed the standard limit.

4.1 Over all ranges of pollutant levels at Puducherry town

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

Pollutant	Range (µg/m^3)	Standard limit (µg/m^3)
SPM	252.63 to 388.72	200
NO_2	84.45 to 124.03	80
SO_2	44.14to 79.91	80
CO	0 to 2.4 (mg/m^3)	2 mg/m^3

The results of the investigations on ambient air quality in Puducherry are on the anticipated lines, making a clear case warranting immediate installation of a "continuous ambient air quality monitoring process" on stream.

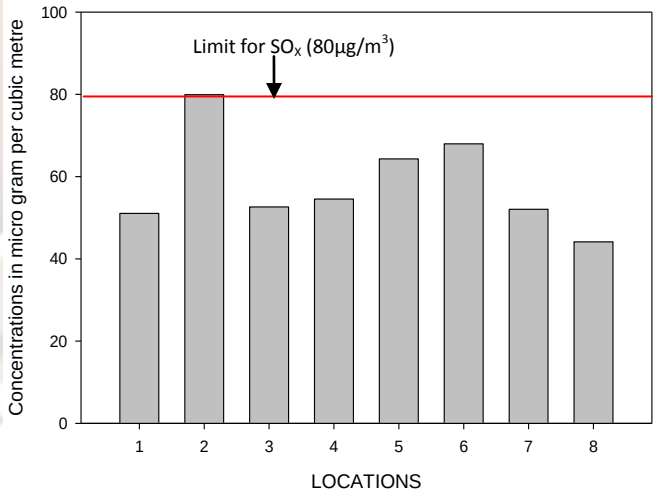

Figure 4.3 Concentrations of Sulphur di oxide against each location

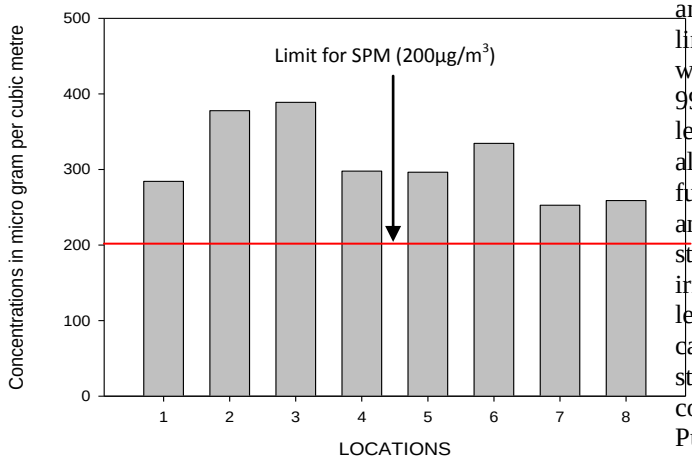

Figure 4.4 Concentrations of Suspended particulate matter against each location

Table 4.1 Result Tabulation

Location	SPM	NO_X	SO_2	CO
	(200µg/m^3)		(80µg/m^3)	(80µg/m^3) mg/m^3 (
Indira Gandhi Signal	**284.20**	**92.76**	51.05	**0-2.4**
Rajiv Gandhi Signal	**377.75**	**124.03**	79.91	**0-2.4**
Bus stand	**388.72**	**91.35**	52.625	**0-2.4**
Kanniya koil	**297.72**	**92.196**	54.541	**0-2.4**
Nehru street	**296.33**	**106.37**	64.31	**0-2.4**
Tindivanam High Road	**334.52**	**112.37**	67.97	**0-2.4**
Cuddalore Main Road	**252.63**	**84.45**	52.05	**0-2.4**
Muruga Theatre Stop	**258.79**	**84.86**	44.14	0-1.2

V CONCLUSION

Criteria pollutant levels of SPM, NO_2 and CO in the ambient air of Puducherry town are found to cross the limits in the four days per site eight hour sampling, while SO_2 level is also considerable at about 99.88%(maximum). It is likely that right now the levels of all the pollutants have crossed the limits at all the sites. The alarming situation will worsen further in future due to further addition of two, three and four wheelers on the road.Preliminary 8 hour 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.

Puducherry 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 ($O_{3)}$, Carbon monoxide (CO_2), Sulfur dioxide (SO_2), Small particulates (PM_{10}), Nitrogen dioxide (NO_2), and the lead (Pb). Additrally CO_2 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.

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