Int. J. Chem. Sci.: 9(3), 2011, 1203-1216
ISSN 0972-768X
www.sadgurupublications.com

AMBIENT AIR QUALITY STUDIES ON VIRUDHACHALAM

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ABSTRACT

During the summer of 2009, samples 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 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 Virudhachalam, 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 SO_x values were not exceeding the National Ambient Air Quality Standard (NAAQS) at all the eight locations. The SPM values exceeded the National Ambient Air Quality Standard (NAAQS) at all the eight locations. The NO_x values exceeded the National Ambient Air Quality Standard (NAAQS) at seven locations. The CO values exceeded the National Ambient Air Quality Standard (NAAQS) at six locations.

Keywords: Ambient air quality, Criteria pollutant, Preliminary assessment, Semi urban air sampling, Transport emissions.

INTRODUCTION

Developed & 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,

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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 is due to, 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, NO_x and HC with each other in the presence of sunlight) causes chest constriction and irritation of the mucous membrane infection.

EXPERIMENTAL

The study area

Virudhachalam is located in Cuddalore District and is 200 km south-west of Chennai. Neyveli is 18 km east of Virudhachalam. The place is famous for a Shiva Temple dedicated to Vridhagiriswarar. The important festival here is the Masi Magam. During this time, pilgrims throng here to have bath in the scared Manimukthar river. Nearest airport is at Tiruchirapalli. Virudhachalam Railway Station is on the Tiruchirapalli-Villupuram line. Virudhachalam (also known as Vriddhachalam) is a municipality and taluk headquarters in Cuddalore district in the Indian state of Tamil Nadu. Vriddhachalam is located at. 11°30′N 79°20′E / 11.50°N 79.33°E / 11.50; 79.33 It has an average elevation of 45 m (148 ft). The name Vriddhachalam is obtained from two Sanskrit words - Vriddham which means old and Achalam which means mountain. So, Vriddhachalam means 'Old Mountain'. It is also called by other name Thirumudhukundram which also means the same. (Thiru = holy, mudhu = old, kundram = hill). It is one of the important railway destination and junction. It serves the midway between Salem, Trichy, Madurai and Chennai rail routes. Very near to Neyveli. Population of Virudhachalam town is around a 1, 59, 300 excluding that of tens of existing and upcoming mini satellite townships surrounding.

Description of sampling sites

Eight sites were selected for Ambient Air Quality (AAQ) monitoring in Virudhachalam. 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, NO_x, SO_x and CO in the Virudhachalam region. Geographical locations of the sampling sites were measured from the meteorological department, Virudhachalam

Palakarai (VDM1)

With gate closures, heavy traffic flow, stop-go opportunity and railway over bridge construction activities. Percentage traffic shares of two wheelers, three wheelers, light vehicles and heavy vehicles were 45, 18, 21 and 16, respectively.

Gandhi Nagar (VDM2)

With 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 and heavy vehicles were 45, 18, 19 and 18, respectively.

Table 1: Details of air quality monitoring station in Virudhachalam, India

Site	Code	Site classification	Monitoring period (10.00 to 06.00)
Palakarai	VDM1	Traffic area	02-04-2009 to 04-04-2009
Gandhi Nagar	VDM 2	Traffic area	05-04-2009 to 07-04-2009
Periyar Nagar	VDM 3	Traffic area	08-04-2009 to 10-04-2009
State Bank Stop	VDM 4	Traffic area	11-04-2009 to 13-04-2009
Kadai Veedhi	VDM5	Traffic area	14-04-2009 to 16-04-2009
Bazzaar Street	VDM6	Traffic area	17-04-2009 to 19-04-2009
Indira Nagar	VDM 7	Traffic area	20-04-2009 to 22-04-2009
Bus Stand	VDM 8	Traffic area	23-04-2009 to 25-04-2009

Periyar Nagar (VDM3)

With 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 and heavy vehicles were 36, 22, 23 and 19, respectively.

State Bank Stop (VDM4)

With 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 and heavy vehicles were 47, 18, 21 and 14, respectively.

Kadai Veedhi (VDM5)

With 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 and heavy vehicles were 42, 20, 22 and 16, respectively.

Bazzaar Street (VDM6)

With gate closures, heavy traffic flow, stop-go opportunity and railway over bridge

construction activities. Percentage traffic shares of two wheelers, three wheelers, light vehicles and heavy vehicles were 47, 17, 22 and 14, respectively.

Indira Nagar (VDM7)

With one way traffic signal, vehicle queuing and narrow sharp turn. Percentage traffic shares of two wheelers,three wheelers, light vehicles and heavy vehicles were 45, 20, 18 and 17, respectively.

Virudhachalam Bus Stand (VDM8)

With 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 and heavy vehicles were 1, 0, 0 and 99, respectively.

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 Whatman grade 1 fiber glass 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 tetrachloromercurate 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).

Suspended particulate matter

High volume air sampler was used for the monitoring of particulates. Before sampling, the whatman filter GFA (20.3 cm x 25.4 cm) 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 415.62 cm^2 portion of the filter at the flow rate of 1.70 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.

Nitrogen oxides

Ambient air was continuously drawn into 35 mL of sodium hydroxide solution at a

flow rate of 2 LPM for 8 hour and Jacobs and Hochhesier method was used in the laboratory to estimate 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 ethylenediamine 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.

Sulphur oxides

Ambient air was continuously drawn into 35 mL of sodium tetrachloromercurate solution at a flow rate of 1.5 LPM for 8 hour and sodium tetrachloromercurate method was used in the laboratory to estimate 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.

RESULTS AND DISCUSSION

Figs. 1 and 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 six of the eight sample sites. SO_2 level has not crossed the limit at all the eight sample sites. NO_X level has crossed the limit at seven 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.

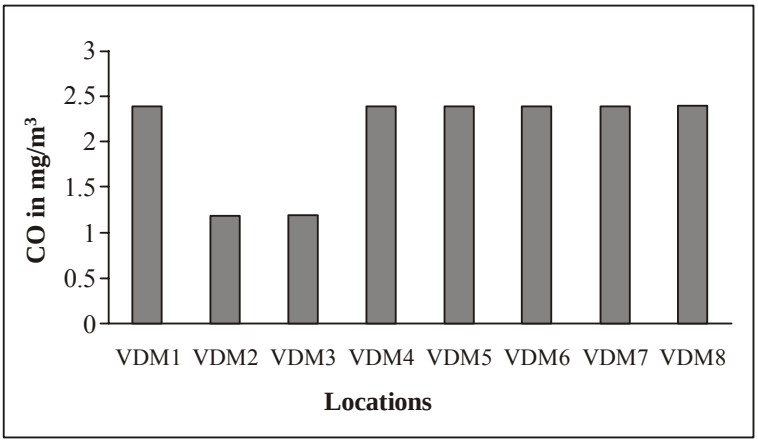


Fig. 1: Ambient air quality in virudhachalam

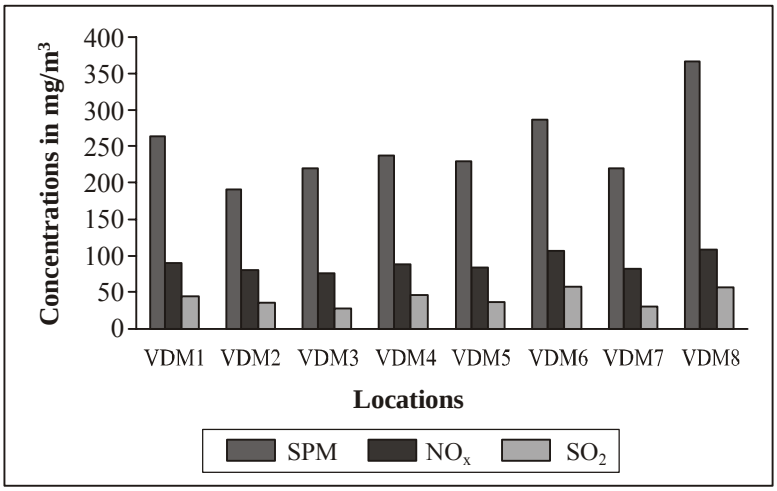


Fig. 1: Ambient air quality in virudhachalam

Figs. 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 99 percent dominate.

There is considerable correlation between pollutant levels and activities at the sites. At bus terminus with intensive transport activities, three pollutants are found to cross the limits (SPM by 183.50%, NO_x by 137.83% and CO by 20%). NOx at the bazzar street with two way traffic system is the second highest (35.22% more than the limit) due to heavy automobile mobility and over bridge construction activity. The only source for NO_2 is the auto emission, in the absence of any other industrial 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.

At Palakarai, having restricted automobile mobility and two-way traffic signal, the pollutant levels are : SPM (265.01 $\mu g/m^3$, 132.50% of the limit) crossed the standard limit. SO_2 (46.262 $\mu g/m^3$, 57.82% of the limit) has not crossed the standard limit. NO_x (92.196 $\mu g/m^3$, 115.24% of the limit) crossed the standard limit. CO (2.4mg/m^3, 120% of the limit) crossed the standard limit.

At Gandhi nagar, having restricted automobile mobility and two-way traffic signal pollutant levels are: NO_2 (82.93 µg/m^3, 103.66 % of the limit) crossed the standard limit. SO_2 (37.208 µg/m^3, 46.51% of the limit) has not crossed the standard limit. SPM (191.84 µg/m^3, 95.92% of the limit) has not crossed the standard limit. CO (1.2 mg/m^3, 60% of the limit) has not crossed the standard limit.

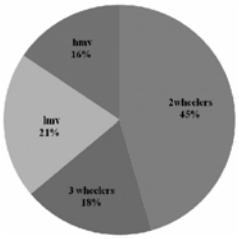
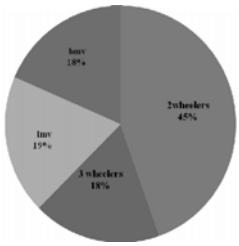
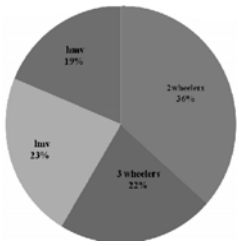
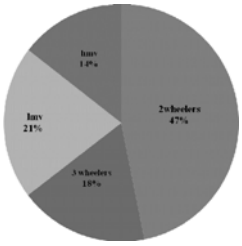
Table 2: Result tabulation

Location	SPM (200 µg/m^3)	NO_x (80 µg/m^3)	SO_x (80 µg/m^3)	CO (mg/m^3)
Palakarai VDM1	265.01	92.196	46.262	0-2.4
Gandhi Nagar VDM 2	191.84	82.93	37.208	0-1.2
Periyar Nagar VDM 3	221.50	77.34	29.993	0-1.2
State Bank Stop VDM 4	239.44	89.20	48.538	0-2.4
Kadai Veedhi VDM5	231.28	85.656	38.953	0-2.4
Bazzaar Street VDM6	289.08	108.18	58.260	0-2.4
Indira Nagar VDM 7	221.13	83.312	32.359	0-2.4
Bus Stand VDM 8	367.47	110.270	58.624	0-2.4

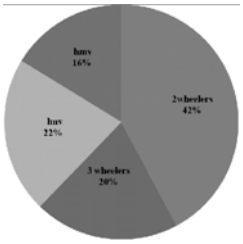
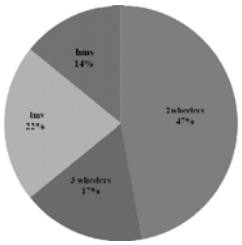
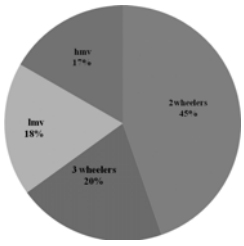
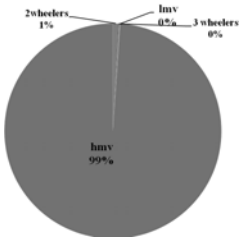
At Periyar nagar with signalized intersection, pollutant levels are: SPM (221.50 µg/m^3, 110.75% of the limit) crossed the standard limit.SO_2 (29.993 µg/m^3, 37.49% of the limit) has not crossed the standard limit. NO_2 (77.34 µg/m^3, 96.67% of the limit) has not crossed the standard limit. CO (1.2 mg/m^3, 60% of the limit) has not crossed the standard limit.

At State bank stop having restricted automobile mobility and two-way traffic signal, the pollutant levels are: SPM (239.44 µg/m^3, 119.72% of the limit) crossed the standard

limit. NO_2 (89.20 μg/m^3, 111.5% of the limit) crossed the standard limit. SO_2 (48.538 μg/m^3, 60.67% of the limit) has not crossed the standard limit. CO (2.4 mg/m^3, 120% of the limit) crossed the standard limit.

Locations	Details and activities	Pie chart details			
Palakarai (VDM1)	Two way, less queuing, less stop-go and bridge construction	 Fig. 3	**Legend**	**%**	**No. of vehicles**
			1	45.00	4756
			2	18.00	1915
			3	21.00	2148
			4	16.00	1625
Gandhi Nagar (VDM2)	Two way, heavy non-smooth flow, narrow sharp turn, and parking lots	 Fig. 4	**Legend**	**%**	**No. of vehicles**
			1	45.00	4013
			2	18.00	1620
			3	19.00	1710
			4	18.00	1667
Periyar Nagar (VDM3)	Two way, queuing, stop-go, open loop traffic signal and vehicle mobility	 Fig. 5	**Legend**	**%**	**No. of vehicles**
			1	36.00	2655
			2	22.00	1597
			3	23.00	1647
			4	19.00	1358
State Bank Stop (VDM4)	Large number of bus operations, queuing, frequent stop-go and repeated driving cycles	 Fig. 6	**Legend**	**%**	**No. of vehicles**
			1	47.00	5263
			2	18.00	1998
			3	21.00	2347
			4	14.00	1630

Cont…

Locations	Details and activities	Pie chart details			
Kadai Veedhi (VDM5)	Two way, less queuing, less stop-go, commercial bazaar	 Fig. 7	**Legend**	**%**	**No. of vehicles**
			1	42.00	4298
			2	20.00	2045
			3	22.00	2190
			4	16.00	1659
Bazzar Street (VDM6)	Two way, traffic signal, heavy non-smooth flow, gate closure, heavy traffic, stop-go, bridge construction	 Fig. 8	**Legend**	**%**	**No. of vehicles**
			1	47.00	5483
			2	17.00	1991
			3	22.00	2516
			4	14.00	1652
Indira Nagar (VDM7)	Two way, traffic signal queuing, narrow sharp turn	 Fig. 9	**Legend**	**%**	**No. of vehicles**
			1	45.00	4172
			2	20.00	1904
			3	18.00	1707
			4	17.00	1559
Bus Stand (VDM8)	Large number of bus operations, queuing, frequent stop-go and repeated driving cycles	 Fig. 10	**Legend**	**%**	**No. of vehicles**
			1	1.00	18
			2	0.00	00
			3	0.00	00
			4	99.00	1710

Note: 1-Two wheelers, **2**-Three wheelers, **3**-Light motor vehicles (LMV), **4**-Heavy motor vehicles (HMV)

Fig. 3-10: Distribution of automobile vehicles during each sample site

At Kadai veedhi having restricted automobile mobility and two-way traffic signal, the pollutant levels are : *SPM* (231.28 μg/m^3, 115.64% of the limit) crossed the standard limits. *NO_2* (85.656 μg/m^3, 107.07% of the limit) crossed the standard limits. SO_2 (38.953 μg/m^3, 48.69% of the limit) have not crossed the standard limit.CO (2.4 mg/m^3, 120% of the limit) crossed the standard limit.

At Bazzar street with two way traffic signal, pollutant levels are; *SPM* (289.08 μg/m^3, 144.54% of the limit) crossed the standard limits. NO_2 (108.18 μg/m^3, 135.22% of the limit) crossed the standard limits. SO_2 (58.260 μ/m^3, 72.825% of the limit) has not crossed the standard limit. CO (2.4 mg/m^3, 120% of the limit) crossed the standard limit.

At Indira nagar having restricted automobile mobility with two-way traffic signal, pollutant levels are; SPM (221.13 μg/m^3, 110.56% of the limit) crossed the standard limits. NO_2 (83.312 μg/m^3, 104.14% of the limit) crossed the standard limits. SO_2 (32.359 μ/m^3, 40.44% of the limit) has not crossed the standard limit. CO (2.4 mg/m^3, 120% of the limit) crossed the standard limit.

At the Virudhachalam bus terminus with intense heavy vehicle mobility, pollutant levels are : SPM (367.47 μg/m^3, 183.73 % of the limit) crossed the standard limit. NO_2 (110.270 μg/m^3, 137.83% of the limit) crossed the standard limit. SO_2 (58.624 μg/m^3, 73.28% of the limit) has not crossed the standard limit. CO (2.4 mg/m^3, 120% of the limit) crossed the standard limit.

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 Virudhachalam, Indian town are summarized here under -

Pollutant	Range (μg/m^3)	Standard limit (μg/m^3)
SPM	191.84 to 367.47	200
NO_x	77.34 to 110.270	80
SO_x	29.993 to 58.624	80
CO	0 to 2.4 (mg/m^3)	2 mg/m^3

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

CONCLUSION

Criteria pollutant levels of SPM, NO_2 and CO in the ambient air of Virudhachalam town are found to cross the limits in the three days per site continuous sampling, while SO_2 level is also considerable at about 73.28% (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.

Virudhachalam 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 worth 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 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.

On the basis of findings of the study, the following 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 or 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.

ACKNOWLEDGEMENT

The assistance offered by the authorities of Annamalai University, its Engineering Chemistry section and Department of Civil Engineering, and the permission of Virudhachalam Municipality are acknowledged. Grateful thanks to Vice Chancellor, Dean and staff members of Department of Mechanical Engineering and Civil Engineering of Annamalai University for their cooperation to carry out this survey.

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Accepted : 08.04.2011