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# Air Pollution Monitoring Using GIS, GPS and Gas Sensors for Chennai City

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Dr. Gregory T. Papanikos
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## Abstract

Indian cities are highly polluted due to rapid urbanization and industrialization resulting in increase of traffic volume in many folds during the past two decades which contributes about 70% of Air Pollution. The metropolitan city Chennai has no exception to it. Air pollution has significant negative impact on public health, vegetation and property. The Central Pollution Control Board (CPCB) and the respective State Pollution Control Boards (SPCBs) have been carrying out air pollution measurements under the National Ambient Air Quality Monitoring (NAAQM) program. Analytical methods spectroscopy or gas chromatography/mass spectrometry is used to test the samples collected using High Volume Sampler (HVS). This method is expensive, laborious and time consuming.

Now-a-days, Nano-technology based Solid State Gas Sensors are available to monitor air quality rapidly. In this regard, Air Quality Monitoring System (AQMS) with gas sensors is designed and developed. It consists of CO, $NO_2$ and $SO_2$ sensors and Global Positioning System (GPS) Antenna. The output of the instrument is connected to the laptop installed with Geographical Information System (GIS) where the monitored data is stored, retrieved and analysed for various purposes like to warn public to stay indoors in case of high levels of air pollution, to plan for control and prevention measures of Air Pollution. In this study, 10 important locations have been identified based on traffic volume in the area and industries situated. The air pollution measurement was carried out at ten places from 8.00 am to 7.00 pm. The study revealed that the pollutant $SO_2$, $NO_2$, and CO concentrations were varied from 0.010 to 0.045 ppm, 0.010 to 0.055 ppm, and 0.7 to 6.4 ppm respectively.

**Keywords:** Air Pollution, Gas Sensors, Air Quality Monitoring System, GIS

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## Introduction

*General*

Urban areas are highly polluted due to more economic activities when compared to rural areas. Especially, the Indian government's decision on economic policies such as liberalization and industrialization during the past two decades, had led to rapid growth of urban population. In addition to it, the Information Technology (IT) boom during 1995 to 2005 had also caused tremendous growth of urban population. It had caused rapid economic development of people due to which, use of private vehicles increased in many folds apart from the public vehicles. Total number of registered motor vehicles in India∗ are as follows;

| Year | 1986 | 1991 | 1996 | 2001 | 2006 | 2011 |
|---|---|---|---|---|---|---|
| Motor Vehicles (millions) | 10.58 | 21.37 | 33.79 | 54.99 | 89.62 | 141.87 |

∗Source: Road Transport Year Book: 2010-11

Emissions from vehicles are contributing around 60 to 70% of the air pollution in cities. The national road traffic contributes 70% to the national CO-emission and completely dominates the CO-pollution in most of the urban areas (Mahboob Ali and Makshoof Athar, 2008).

On August 2, 2012, Hong Kong urged residents to stay indoors as the city choked under the worst cloud of man-made air pollution the city has ever recorded (Aaron Tam, August-2012). It will not be a surprise if such episodes occur in Metropolitan cities of India in the near feature.

*Chennai City*

As per 2011 census, the Chennai city has population of 46,81,087 and its urban / metropolitan population is 86,96,010. It is one of the fast developing metropolitan cities in India. There are about 27 lakhs registered vehicles in the Chennai City. As the city is one of the main business centers in India, there is lot of floating population also coming to city by using personnel vehicles as well as public transport. The city has ample number of hospitals with good infrastructure facilities, domestic as well as international Airport, good rail and bus connectivity to various places throughout India. The city has within it lot of commercial establishments including good hotels, IT parks, small, medium and large scale industries and well established government and private educational institutions.

*Air Pollution Monitoring Process*

Central Pollution Control Board had identified four major air pollutants, namely, SPM, CO, SO2 and NO2 for regular monitoring at selected 290 stations spread across the country under the National Ambient Air Quality Monitoring (NAAQM) network. In Chennai, ambient air quality is monitored at five stations, namely, Anna Nagar, T. Nagar, Adyar, Vallalar Nagar, and Kilpauk by the Tamil Nadu State Pollution Control Board using High Volume Sampler for 104 days in a year in each station by the conventional analytical procedure. Now, it is proposed to set up 5 more monitoring stations (The Hindu e-paper, 2011).

The analyzers which are complex and bulky equipment allow precise concentration measurements of gaseous pollutants in air. However, the lengthy air sampling and data processing do not allow ‘real time’ dissemination of the information to the public. AQM systems based on cost-effective semiconductor gas sensors reduces the cost of stations thereby making possible to implement dense networks in every large city in every country (Marie-Isabelle Baraton and Lhadi Merhari, 2004).

Monitoring of Air Pollution by using AQMS instrument with gas sensors is inexpensive and rapid. This system is very compact and portable (Duk-Dong Lee & Dae-Sik Lee, 2001). It can be used for real time monitoring by connecting and uploading the monitored data to the website designed exclusively for this purpose (O. Pummakarnchana, & N. K. Tripathi, 2006).

With the rapid development of micro-electro-mechanical systems and Wireless Sensor Network (WSN) technology, it is possible to create cost effective & low power air quality monitoring system. The integration of an air pollutant monitoring system with WSN technology will reduce installation costs and enable the quick and easy reconfiguration of the data acquisition and control systems (Tajne K.M., et. al., 2011).

*Objectives*

i) To design and develop an air quality monitoring system with solid state gas sensors.
ii) To use the instrument with sensor system for monitoring air pollution.
iii) To find the levels of air pollution concentrations at important locations in the Chennai city.

## Materials and Methodology

*Development of AQMS Instrument with Sensors*

Air Quality Monitoring System (AQMS) instrument with Sensors is designed and developed using ARM Processor which is used to link different types of inputs such as Solid State Gas Sensors, GPS Antenna and outputs such as PC/Laptop or LCD display. This ARM Processor with input and output devices is collectively known as AQMS instrument. The ARM processor is LPC2119/LPC2129 type based on a 16/32 bit ARM7TDMI-S, CPU with real-time emulation and embedded trace support, together with 128/256 kilobytes (kB) of embedded high speed ßash memory. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at maximum clock rate. For critical code size applications, the alternative 16-bit Thumb

Mode reduces code by more than 30% with minimal performance penalty. With their compact 64 pin package, low power consumption, various 32-bit timers, 4-channel 10-bit ADC, 2 advanced CAN channels, PWM channels and 46 GPIO lines with up to 9 external interrupt pins, these microcontrollers are particularly suitable for automotive and industrial control applications as well as medical systems and fault-tolerant maintenance buses. With a wide range of additional serial communications interfaces, they are also suited for communication gateways and protocol converters as well as many other general-purpose applications.

In the AQMS instrument, the Solid State Gas Sensors of CO, $NO_2$, $SO_2$ and GPS Antenna are linked through ARM processor. The block diagram of the AQMS instrument is shown in Figure 1 and the photograph of the instrument is shown in Figure 2. The air pollution output data from this instrument can be recorded either manually by seeing on the LCD display (or) connected to PC/Laptop and stored. The AQMS instrument also helps in uploading the linked data to the Internet. Hence, the monitored pollution data can be uploaded to the internet for viewing and taking appropriate action by the stake holders to safe guard themselves.

**Figure 1.** *AQMS Instrument Block Diagram*

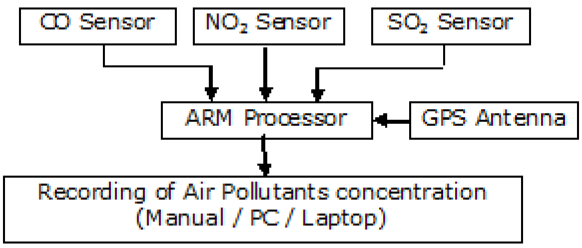
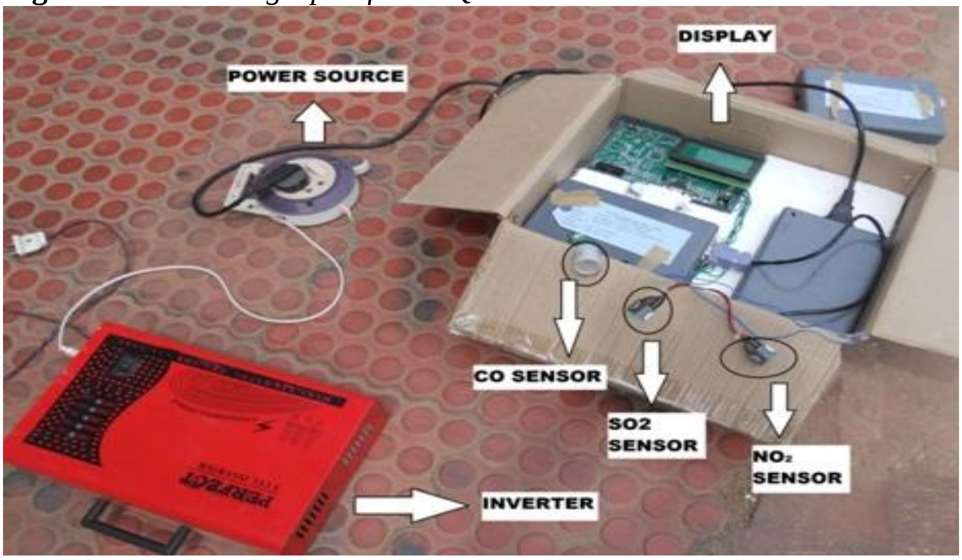



**Figure 2.** *The Photograph of the AQMS Instrument*



*Selection of Air Pollution Monitoring Stations*

Monitoring stations (totally 10 stations) are selected by giving importance to the areas of high traffic volume, industrial and commercial activities. The selected two stations are near to commercially busy area (T. Nagar and Avadi bus stand), five stations are on high volume traffic routes in the heart of city, (Paris corner near Fort station, Thiruvanmiyur signal near Jayanthi theatre, Pallavaram station on GST Road, Porur signal on Poonamallee High Road, and Ashok pillar signal near Ashok Pillar), and three stations are near to industrial activities, namely Ambattur industrial estate, Guindy industrial estate and Manali have been selected.

*Methodology*

AQMS instrument with Solid State Gas Sensors and GPS Antenna is designed and developed for the purpose of monitoring of the air pollutants concentration. The gas sensors are calibrated using an indigenously developed exponential gas dilution system hyphenated with Teflon coated canisters (Jayakumar I., 2005). Sites of Air Pollution monitored stations are shown in the figure 3 (Google earth map). The sites S1 to S10 are T. Nagar bus stand (S1), Avadi bus stand (S2), Paris Corner (S3), Thiruvanmiyur Signal (S4), Pallavaram Station (S5), Porur Signal (S6), Ashok Pillar Signal (S7), Ambattur Industrial Estate (S8), Guindy Industrial Estate (S9) and Manali (S10) respectively.

**Figure 3.** *The Locations of Air Pollution Monitoring Stations*


Monitoring point at each site is fixed at a distance 5m from the edge of the road and 1m above the road level in the windward direction, and also enough care has been taken that there is no obstruction within 2m radius from the center of the instrument so that the free air flow is ensured.

AQMS instrument with $SO_2$, $NO_2$and CO gas sensors was used to monitor the air pollutants' concentration. The Air Pollutants' concentrations were monitored and recorded once in every one hour from 8.00 am to 7.00 pm on each day and for three days at each site. The air pollution monitoring was carried out from 12-11-2012 to 15-12-2012 except Sundays. The mean values are presented in the Table 1.

*Validation of Pollutant Concentration Measurements*

The Tamil Nadu Pollution Control Board (TNPCB) located at Chennai has been monitoring Ambient Air Quality which publishes pollutants concentration on its website www.tnpcb.nic.in. The readings from it are considered for validation. The readings measured at T.Nagar by TNPCB for November 2012 are considered since AQMS instrument is used during 12-11-2012 to 14-11-2012 from 8.00 am to 7.00 pm every day for measuring pollutant concentration. The same is tabulated below. TNPCB readings are monthly average concentrations whereas AQMS instrument readings are 36 hours average concentrations.

| **Month** | **Pollutant** | **Pollutant concentration in ppm at T. Nagar** | |
|---|---|---|---|
| | | **Using conventional (analytical) method** | **Using AQMS instrument** |
| November 2012 | $SO_2$ | 0.005 | 0.0229 |
| | $NO_2$ | 0.0187 | 0.0313 |

Readings at T. Nagar are compared since monitoring done using AQMS instrument is also near to TNPCB monitoring site. It is 30 m away from the instrument and 35 m from the main road. There are two reasons why we found the significance difference between the two measurements. First of all the conventional method adopted by TNPCB takes sampling continuously for 24 hours and sends it to laboratory for analysis. During night concentration drastically reduces due to lack of traffic volume and consequently sampling gets very low concentration of pollutants. So the average concentration comes down. Secondly the distance of monitoring from the main road also has its own effect on reactive nature of pollutants. By the time they reaches the monitoring site of TNPCB, the concentration shall be diluted and hence the results obtained in the laboratory are very less than the concentration measured using the AQMS instrument located at 5m from the edge of the road. Therefore the difference of that sort is possible between both methods. Thus the readings obtained using AQMS instrument are comparatively holds good.

**Table 1.** *Mean Concentration of Air Pollutants monitored at Ten Locations*

| Time | T. Nagar bus stand | | | Avadi bus stand | | | Paris Corner | | | Thiruvanmiyur signal | | | Pallavaram station | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO |
| 08.00 | 0.010 | 0.015 | 0.7 | 0.015 | 0.025 | 1.2 | 0.015 | 0.020 | 1.5 | 0.020 | 0.020 | 0.9 | 0.015 | 0.015 | 0.9 |
| 09.00 | 0.025 | 0.025 | 1.6 | 0.015 | 0.025 | 3.0 | 0.025 | 0.040 | 1.7 | 0.020 | 0.030 | 2.3 | 0.020 | 0.020 | 1.5 |
| 10.00 | 0.025 | 0.030 | 4.3 | 0.020 | 0.035 | 3.4 | 0.035 | 0.045 | 3.1 | 0.025 | 0.045 | 4.0 | 0.020 | 0.035 | 3.0 |
| 11.00 | 0.035 | 0.045 | 3.1 | 0.025 | 0.030 | 3.5 | 0.035 | 0.055 | 6.4 | 0.035 | 0.040 | 4.2 | 0.025 | 0.030 | 3.3 |
| 12.00 | 0.020 | 0.045 | 2.6 | 0.025 | 0.025 | 3.6 | 0.020 | 0.030 | 4.0 | 0.020 | 0.030 | 4.0 | 0.025 | 0.035 | 4.2 |
| 13.00 | 0.010 | 0.040 | 2.2 | 0.015 | 0.025 | 2.0 | 0.025 | 0.030 | 3.6 | 0.025 | 0.030 | 3.6 | 0.030 | 0.040 | 3.0 |
| 14.00 | 0.020 | 0.030 | 1.6 | 0.025 | 0.030 | 2.5 | 0.025 | 0.025 | 2.4 | 0.025 | 0.025 | 3.2 | 0.025 | 0.025 | 2.4 |
| 15.00 | 0.020 | 0.035 | 1.3 | 0.035 | 0.045 | 4.5 | 0.030 | 0.030 | 3.2 | 0.020 | 0.020 | 2.4 | 0.025 | 0.030 | 2.6 |
| 16.00 | 0.020 | 0.030 | 1.6 | 0.025 | 0.050 | 5.2 | 0.030 | 0.040 | 3.6 | 0.025 | 0.035 | 1.8 | 0.030 | 0.040 | 2.5 |
| 17.00 | 0.025 | 0.035 | 6.0 | 0.035 | 0.045 | 4.8 | 0.045 | 0.045 | 4.2 | 0.025 | 0.035 | 2.4 | 0.035 | 0.040 | 3.2 |
| 18.00 | 0.035 | 0.025 | 3.6 | 0.025 | 0.040 | 4.6 | 0.035 | 0.045 | 4.4 | 0.035 | 0.040 | 4.2 | 0.035 | 0.035 | 3.8 |
| 19.00 | 0.030 | 0.020 | 4.2 | 0.025 | 0.035 | 3.6 | 0.035 | 0.040 | 4.4 | 0.035 | 0.045 | 4.5 | 0.030 | 0.035 | 3.3 |
| Time | Porur signal | | | Ashok Pillar signal | | | Ambattur Industrial Estate | | | Guindy Industrial Estate | | | Manali | | |
| | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO | $SO_2$ | $NO_2$ | CO |
| 08.00 | 0.015 | 0.020 | 1.7 | 0.010 | 0.015 | 0.9 | 0.015 | 0.015 | 1.1 | 0.015 | 0.020 | 1.5 | 0.020 | 0.020 | 1.5 |
| 09.00 | 0.025 | 0.030 | 2.3 | 0.015 | 0.020 | 1.7 | 0.015 | 0.020 | 1.4 | 0.020 | 0.030 | 2.1 | 0.030 | 0.025 | 1.4 |
| 10.00 | 0.030 | 0.045 | 4.2 | 0.015 | 0.030 | 1.8 | 0.025 | 0.030 | 1.9 | 0.025 | 0.030 | 2.3 | 0.035 | 0.025 | 1.6 |
| 11.00 | 0.030 | 0.030 | 3.0 | 0.020 | 0.030 | 3.0 | 0.020 | 0.030 | 2.7 | 0.025 | 0.040 | 3.5 | 0.035 | 0.030 | 2.1 |
| 12.00 | 0.020 | 0.035 | 3.2 | 0.015 | 0.025 | 3.0 | 0.025 | 0.025 | 3.1 | 0.030 | 0.040 | 3.1 | 0.030 | 0.030 | 1.9 |
| 13.00 | 0.020 | 0.030 | 3.5 | 0.020 | 0.035 | 2.2 | 0.025 | 0.025 | 2.7 | 0.030 | 0.035 | 2.2 | 0.035 | 0.035 | 2.3 |
| 14.00 | 0.025 | 0.025 | 2.7 | 0.020 | 0.030 | 2.8 | 0.030 | 0.030 | 1.4 | 0.025 | 0.035 | 2.1 | 0.030 | 0.035 | 1.7 |
| 15.00 | 0.030 | 0.025 | 2.6 | 0.025 | 0.020 | 2.1 | 0.025 | 0.030 | 1.5 | 0.025 | 0.035 | 2.5 | 0.030 | 0.030 | 2.3 |
| 16.00 | 0.030 | 0.035 | 3.2 | 0.035 | 0.035 | 3.0 | 0.025 | 0.035 | 1.8 | 0.030 | 0.040 | 2.6 | 0.040 | 0.045 | 4.0 |
| 17.00 | 0.040 | 0.050 | 5.1 | 0.040 | 0.040 | 4.2 | 0.040 | 0.045 | 2.7 | 0.045 | 0.045 | 3.2 | 0.045 | 0.050 | 4.6 |
| 18.00 | 0.040 | 0.050 | 5.2 | 0.040 | 0.040 | 4.7 | 0.040 | 0.045 | 3.3 | 0.045 | 0.050 | 3.9 | 0.045 | 0.045 | 4.2 |
| 19.00 | 0.035 | 0.040 | 4.6 | 0.035 | 0.030 | 4.1 | 0.030 | 0.030 | 1.8 | 0.040 | 0.040 | 2.8 | 0.040 | 0.035 | 3.4 |

## Results and Discussions

Table 2 shows the Air Quality Index (AQI) of Priority Pollutants. This Air Quality Index is set by the United States Environmental Protection Agency (USEPA) for Ambient Air Quality.

**Table 2.** *Air Quality Index for Priority Pollutants*

| AQI Category | CO (ppm) | $NO_2$ (ppm) | $SO_2$ (ppm) |
|---|---|---|---|
| Very good (0 – 15) | 0 – 2 | 0 – 0.02 | 0 – 0.02 |
| Good (16 – 31) | 2.1 – 4.0 | 0.02 – 0.03 | 0.02 – 0.03 |
| Moderate (32 – 49) | 4.1 – 6.0 | 0.03 – 0.04 | 0.03 – 0.04 |
| Poor (50 – 99) | 6.1 – 9.0 | 0.04 – 0.06 | 0.04 – 0.06 |
| Very Poor (100 or over) | > 9.0 | > 0.06 | > 0.06 |

From the table 1, it was observed in all the monitoring stations that in the morning the pollutants concentration was low due to the less traffic volume and working of only few industries during night time. It was observed that the high concentration of pollutants have occurred between10.00 am and 12.00 Noon and in the evening between 4.00 pm and 6.00 pm. It was observed that mostly during this time, there was either slow movement of traffic or traffic congestions.

The concentration of air pollutants as seen in the Table 1 is mostly falling under the Air Quality Index category of Very Good (0 – 15) to Moderate (32 – 49) with reference to the Table 2, norms set by the USEPA. On careful observation of Table 1, it is found that $SO_2$ exceeded the moderate levels at Paris corner, Guindy Industrial Estate and Manali, $NO_2$ recorded more than moderate levels at all most all stations except Pallavaram Station and Ashok Pillar Signal and CO recorded at all the places within the range of moderate level exceeding it at Paris Corner.

**Figure 4.** *Mean $SO_2$ concentrations observed at side by Bus Stands*

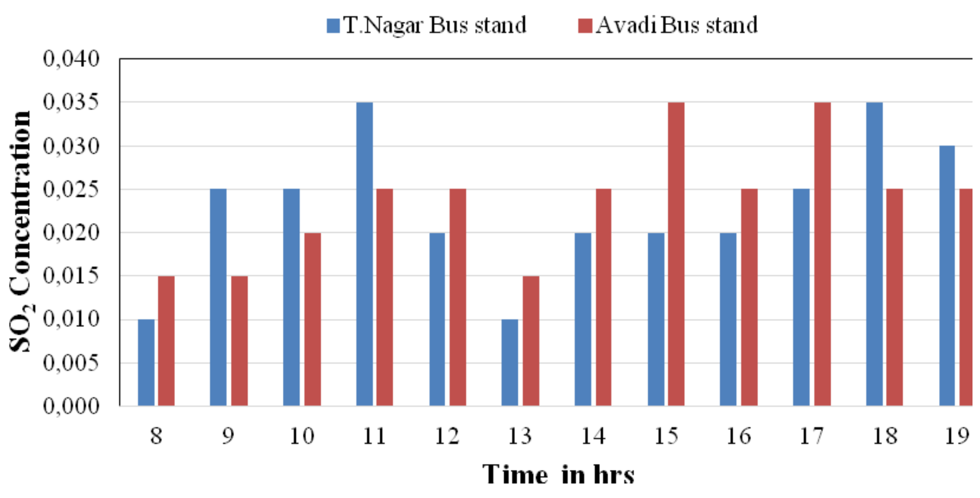


**Figure 5.** *Mean $SO_2$ concentrations observed at High Traffic Volume Routes*

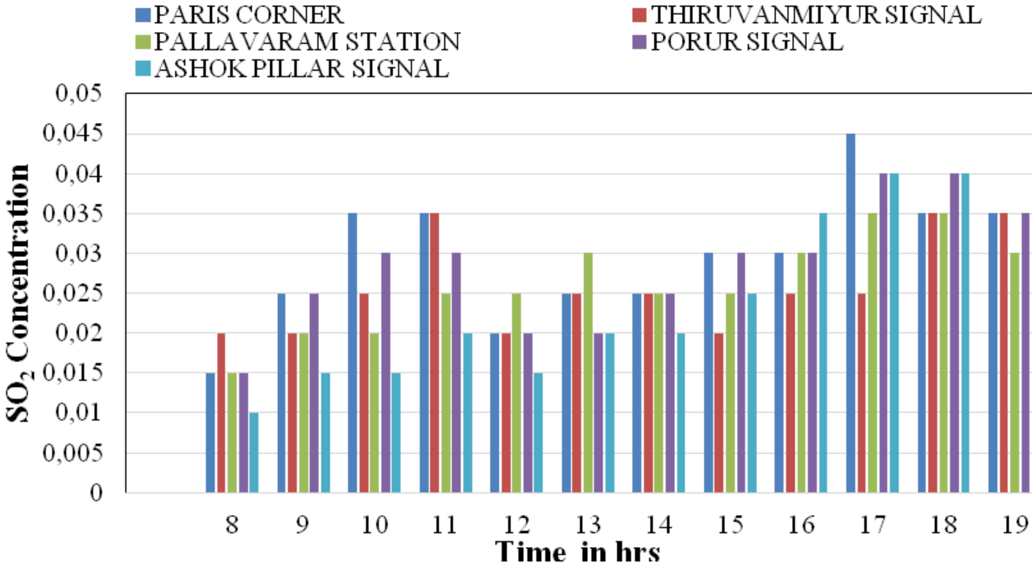



**Figure 6.** *Mean $SO_2$ concentrations observed at Industrial Places*

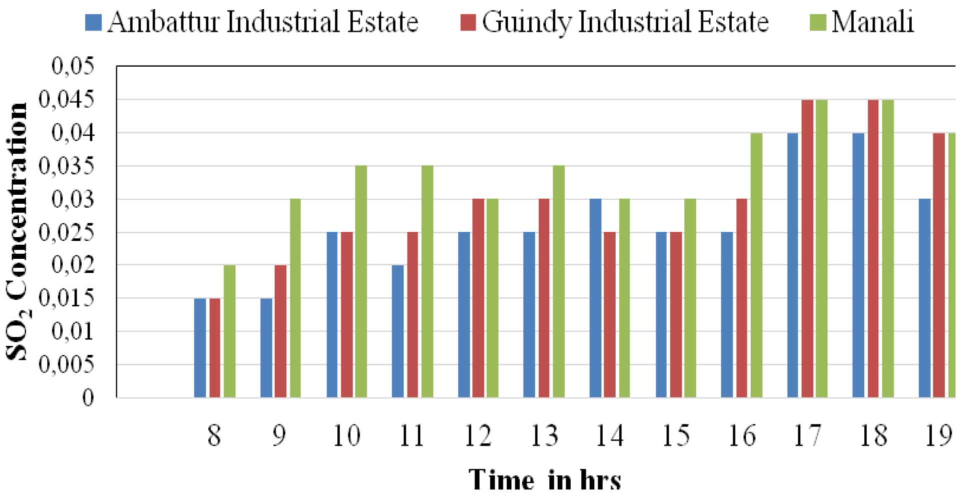



Figure 4, 5 and 6 show the mean observed values of $SO_2$ nearby Bus Stands, High Traffic Routes and Industrial places respectively. These values are varied from 0.10 to 0.035 ppm at both Bus Stands and higher values are though equal but occurred at different timings. In high traffic volume routes the most of the values are between 0.020 and 0.040 ppm. At industrial places they varied between 0.020 and 0.045 ppm.

**Figure 7.** *Mean $NO_2$ concentrations observed at side by the Bus Stands*

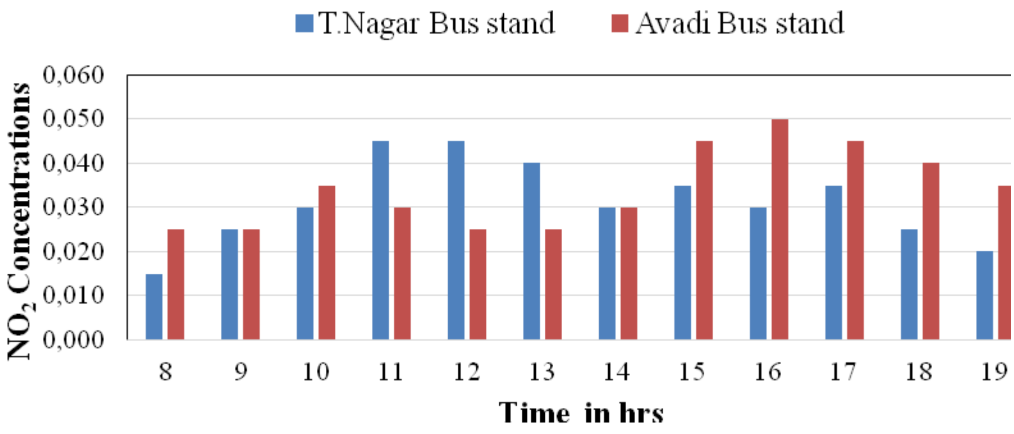



**Figure 8.** *Mean $NO_2$ concentrations observed at High Traffic Volume Routes*

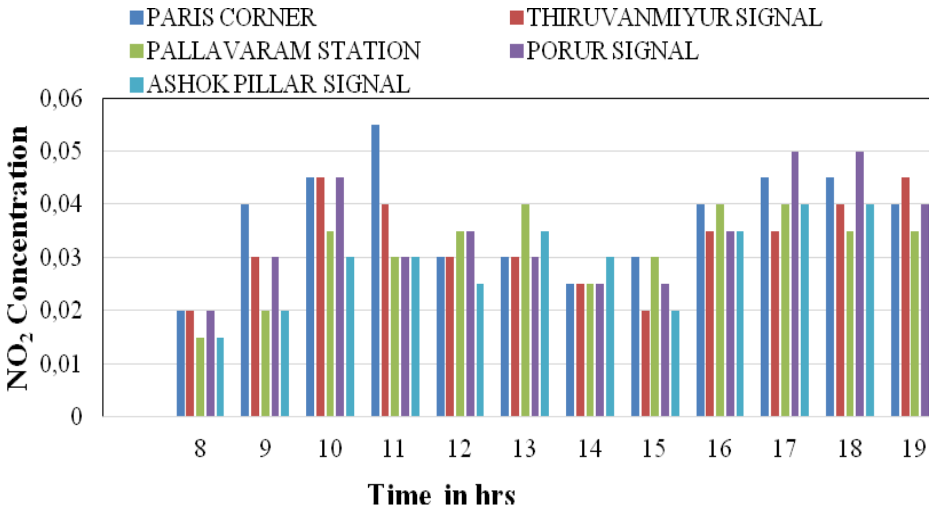



**Figure 9.** *Mean $NO_2$ Concentrations Observed at Industrial Places*

Figure 7, 8 and 9 show the mean observed values of $NO_2$ nearby Bus Stands, High Traffic Routes and Industrial places respectively. These values are mostly varied between 0.20 and 0.045 ppm except 0.050 ppm recorded high at Avadi Bus Stand at 4.00 pm. In high traffic volume routes the most of the values are varied between 0.020 and 0.050 ppm except the high value recorded 0.055 ppm recorded at Paris Corner at 11.00 am. At industrial places the concentration values mostly varied between 0.030 and 0.050 ppm.

**Figure 10.** *Mean CO concentrations observed at side by Bus Stands*

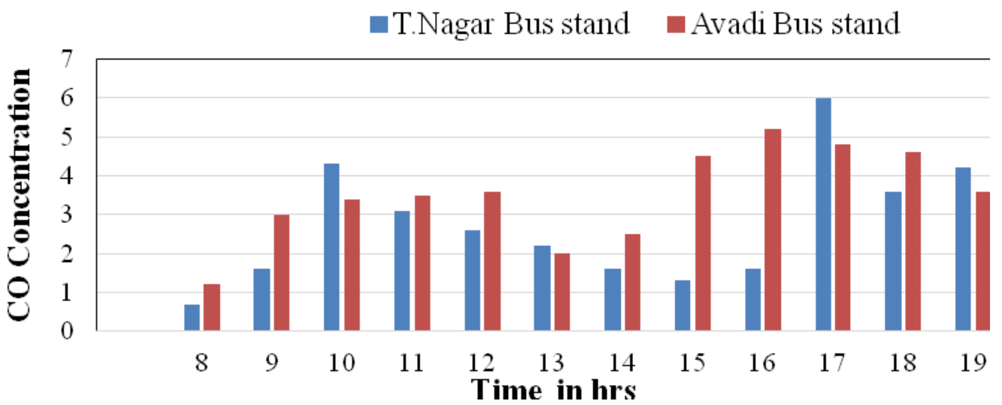



**Figure 11.** *Mean CO concentrations observed at High Traffic Volume Routes*


**Figure 12.** *Mean CO concentrations observed at Industrial Places*

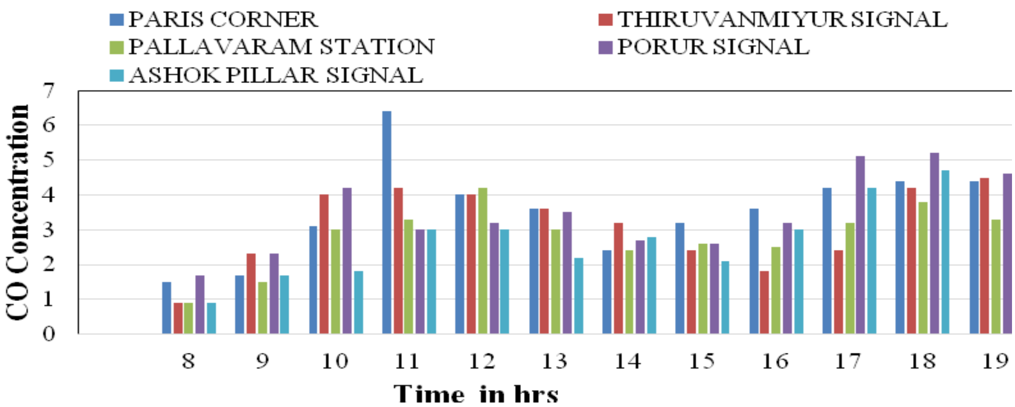


Figure 10, 11 and 12 show the mean observed values of CO nearby Bus Stands, High Traffic Routes and Industrial places respectively. The CO concentrations varied between 1.0 and 6.0 ppm at both Bus Stands. In high traffic volume routes the most of the values varied between 1.0 and 5.2 ppm except recording high value 6.4 ppm at Paris Corner at 11.00 am. The CO concentrations at industrial places recorded between 1.0 and 4.6 ppm.

## Conclusions

The AQMS instrument developed is very handy to monitor Air Pollutants concentrations as compared to the High Volume Sampler. It can also be used for mobile monitoring by fixing it on a vehicle. In short time, more area can be covered to monitor the air pollutants. The readings obtained are as good as that of High Volume Sampler. Further the readings can be connected to internet for real time monitoring which shall be useful to take immediate action in case of high pollution levels, if recorded.

Further, Laptop installed with the software Geographical Information System (GIS) shall help in analysis of pollution data with spatial attributes in the required format which can be used for taking necessary steps in order to mitigate the problems aroused due to air pollution. The benefits of the sensor based Air Quality Monitoring System are as follows.

i. This instrument is less expensive and rapid to measure air pollutants.
ii. Immediate action can be initiated, if found high pollutant levels.
iii. More number of readings can be noted and model can be developed using this data.
iv. No skilled personnel is required to monitor the air pollutants.
v. It is portable, hence easy to handle.
vi. With few modifications the information (pollution data) can be transmitted to the server through laptop and uploaded to the internet for the benefit of people.

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