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Urban Air Pollution – Trend and Forecasting of Major Pollutants by Timeseries Analysis

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***Abstract*—**The Bangalore City is facing the acute problem of pollution in the atmosphere due to the heavy increase in the traffic and developmental activities in recent years. The present study is an attempt in the direction to assess trend of the ambient air quality status of three stations, viz., AMCO Batteries Factory, Mysore Road, GRAPHITE INDIA FACTORY, KHB Industrial Area, Whitefield and Ananda Rao Circle, Gandhinagar with respect to some of the major criteria pollutants such as Total Suspended particular matter (SPM), Oxides of nitrogen (NO_x), and Oxides of sulphur (SO_2). The sites are representative of various kinds of growths viz., commercial, residential and industrial, prevailing in Bangalore, which are contributing to air pollution. The concentration of Sulphur Dioxide (SO_2) at all locations showed a falling trend due to use of refined petrol and diesel in the recent years. The concentration of Oxides of nitrogen (NO_x) showed an increasing trend but was within the permissible limits. The concentration of the Suspended particular matter (SPM) showed the mixed trend. The correlation between model and observed values is found to vary from 0.4 to 0.7 for SO_2, 0.45 to 0.65 for NO_x and 0.4 to 0.6 for SPM. About 80% of data is observed to fall within the error band of ±50%. Forecast test for the best fit models showed the same trend as actual values in most of the cases. However, the deviation observed in few cases could be attributed to change in quality of petro products, increase in the volume of traffic, introduction of LPG as fuel in many types of automobiles, poor condition of roads, prevailing meteorological conditions, etc.

***Keywords*—**Bangalore, urban air pollution, time series analysis.

I. INTRODUCTION

CITIES, by nature, are concentration of human and material activities. They, therefore, exhibit both the highest levels of air pollution and are largest targets of impact [2]. Air pollution is however enacted on all geographical and temporal scales, ranging from strictly 'here' and 'now' problems related to human health and material damage. Episodes of poor air quality in cities, of both developed and developing countries, indicated need of local air quality management system to protect humans and material from the adverse effects of air pollution [3]. India, one of the fast developing countries of the world, registered a sharp increase in vehicular pollution in urban atmosphere [1].

Many metro cities in the country namely Delhi, Mumbai, Calcutta, Madras and Bangalore are experiencing poor air quality, especially in their central business district (CBD) as well as along arterial roads during adverse meteorological conditions. In majority of the cities, air quality management needs to be given most attention for reducing traffic emissions.

Some definitions of 'Pollution' are:

'Pollution implies the increase, or even decrease, of any atmospheric constituent from the value that would have existed without human activity.' [6]

'The presence of substances in the ambient atmosphere, resulting from the activity of man or from natural processes, causing adverse effects to man and environment.' [2] All the above definitions show that air pollution is nothing but addition of undesirable substances to the atmosphere. So according to WHO, the quality of air is divided into 4 levels as shown below [7].

Level I: The contained pollutants are so small (under a specified level) that they have no direct or indirect effect.

Level II: The contained pollutants stimulate the sensory organs, harmfully influence plants, decrease the visibility and have other harmful effects on the environment.

Level III: The contained pollutants cause chronic diseases or shorten the life span.

Level IV: The contained pollutants cause acute diseases and kill some in highly sensitive people.

The Bangalore City is facing the acute problem of pollution in the atmosphere due to the heavy increase in the traffic and developmental activities in recent years. The problem could be more severe in the future in viewing the rate at which the developmental activities are being taken up. Hence, deeper study is required to understand variations of the major criteria pollutants in the city. The present study is an attempt in this direction to assess trend of the ambient air quality status of selected three major stations.

The following are the main objectives of the present study:

- To determine the trend of the concentrations of major air pollutants viz., Sulphur dioxide, Nitrogen oxide and Suspended particulate matter in the ambient air.
- To fit forecast model for the concentrations of the air pollutants.
- To determine the associated factors which contributes towards air pollution.

II. STUDY AREA

Bangalore is the capital of Karnataka state and is located at the centre of southern peninsula of India at 77°35' E longitude and 12°58' N latitude. The ever increasing population due to its yearound comfortable climate (altitude 931 Mt. above MSL) has made the city 5th most populous metropolis in the country. According to 2008census the population is 8.678 Million with local vehicle cruising through out the day and

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has reached 31.29 Lakhs with an addition of 3 lakhs vehicle from other places coming in and going out everyday. These vehicles are accommodated on about 7200 km road network in the city. Of these about 75% of the vehicles are 2 wheelers, added to it with diesel engine light vehicles. About 15% of the vehicles are 4 wheelers with a total of about 90% of the vehicles releasing carbon monoxide and hydro carbons to the city ambient air to create lethal gas chamber [4].

The stations considered for the investigation are AMCO Batteries Factory, Mysore Road, GRAPHITE INDIA FACTORY, KHB Industrial Area, Whitefield and Ananda Rao Circle, Gandhinagar with respect to some of the major criteria pollutants such as Total Suspended particular matter (SPM), Oxides of nitrogen (NO_x), and Oxides of Sulphur (SO_2). The sites are representative of various kinds of growths viz., commercial, residential and industrial, prevailing in Bangalore, which are contributing to air pollution. AMCO factory area is mainly residential with pockets of small scale industries nearby. GRAPHITE INDIA FACTORY, KHB Industrial Estate is mainly industrial area with pockets of residential areas in the vicinity. Ananda Rao Circle (not operational now) is purely commercial area and one of the busiest locality in the city. The Fig. 1 shows the locations of the stations.

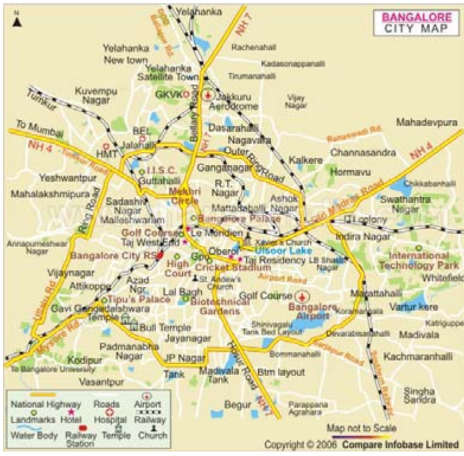
III. DATA COLLECTION

A. Analysis of data by Time Series Analysis

The data collected is analysed using time series analysis concept. A time series is a set of observations taken at specific times, usually at equal intervals. Mathematically, a time series is defined by the values Y_1, Y_2,….. of a variable Y (temperature, closing price of a share, etc.) at times t_1, t_2,….. . Thus Y is a function of t; this is symbolized by Y = F (t) [5]. There are two main goals of time series analysis: (a) identifying the nature of the phenomenon represented by the sequence of observations and (b) forecasting (predicting future values of the time series variable). A software (Minitab), which is compatible to study the time series analysis is used in the present study.

Minitab 15 is a Statistical Software by Minitab Inc. USA, which is extensively used in corporate world and in academics in Statistical Analysis. Minitab 15 is not only simple to use for the beginning or occasional user, but also contains the depth and breadth of tools and guidance to satisfy even the most rigorous quality. Minitab 15 gives the statistical tools one needs to analyze the data and improve quality in one easy-to-use package. It is the leading software used to implement Six Sigma worldwide improvement projects. Minitab computes three measures of accuracy to the fitted model namely MAPE, MAD and MSD, which can be used to compare the fits obtained by using different methods. For all three measures, smaller values generally indicate a better fit model.

Mean absolute percentage error (MAPE) – Expresses accuracy as a percentage of the error. Because this number is a percentage, it may be easier to understand than the other statistics. For example, if the MAPE is 5, on average the forecast is off by 5%.



AQM1 – AMCO Batteries Factory, Mysore Road
AQM2 – GRAPHITE INDIA FACTORY, KHB Industrial Area, Whitefield
AQM3 – Ananda Rao Circle, Gandhi Nagar

Fig. 1 Location of Monitoring Stations

Mean absolute deviation (MAD) – Expresses accuracy in the same units as the data, which helps conceptualize the amount of error. Outliers have less of an effect on MAD than on MSD.

Mean squared deviation (MSD) – A commonly-used measure of accuracy of fitted time series values. Outliers have more influence on MSD than MAD.

Fig. 2 shows the different steps involved in the time series analysis using the software.

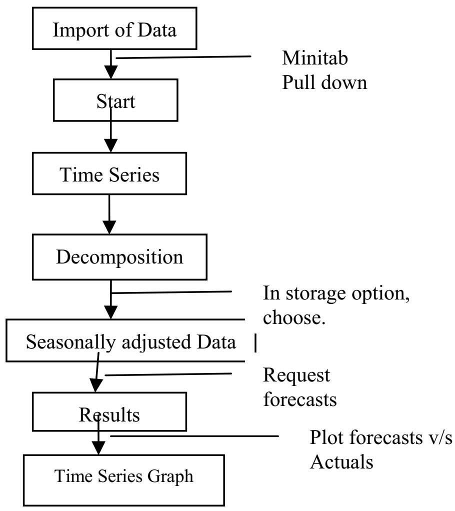


Fig. 2 Steps involved in Minitab Analysis (Decomposition)

III. RESULTS

The Figs. 3 to 5 show the trends of SO_2 for the MAs 12, 24 and 36 respectively for the Station AMCO Batteries for the years 1994-2003. The accuracy measures in the box indicate the statistical details of the plot.

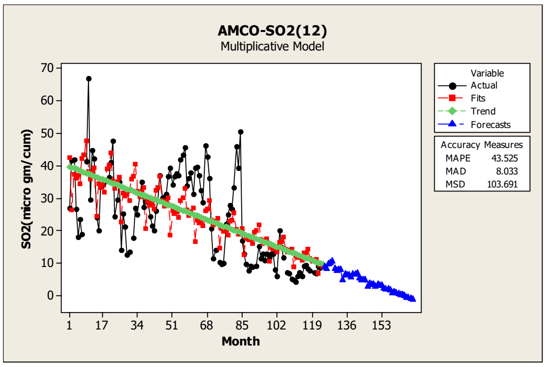


Fig. 3 Timeseries graph for SO_2 at AMCO batteries site with MA12

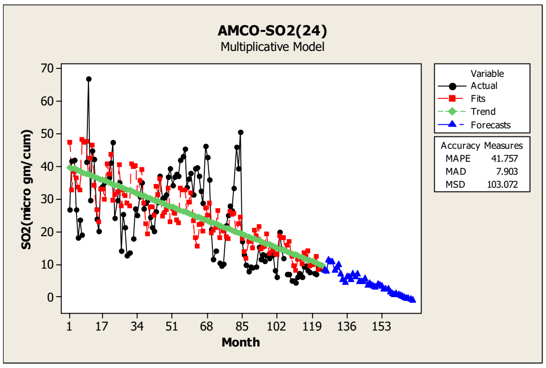


Fig. 4 Timeseries graph for SO_2 at AMCO batteries site with MA24

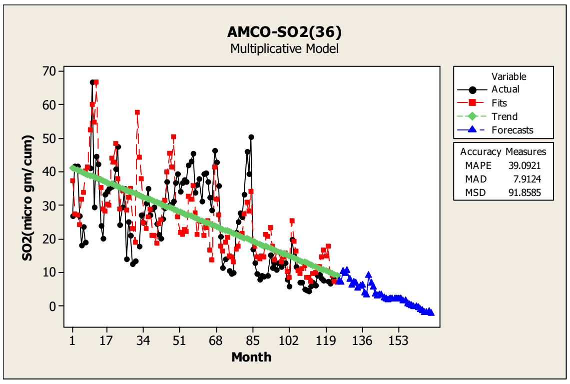


Fig. 5 Timeseries graph for SO_2 at AMCO batteries site with MA36

For each pollutant at all three AQMs, the analysis is carried out with moving averages of 12, 24 and 36 months respectively. As discussed earlier, in Minitab analysis, a model is termed 'Best fit' if the values of three measures of accuracy MAPE, MAD and MSD have the least values. For example, among the analysis of SO_2 at AMCO batteries site (Figs. 3, 4 &5), the best fit would be MA 36 months as the statistical parameters show the least values.

To confirm this, additional statistical measures (beside MSD) like Coefficient of efficiency (r_{se}), Residual mass curve coefficient (r_{mcs}) and Square of Correlation (r_{sq}) are also calculated as suggested by Gouch et.al.[8] and Aitken [4] respectively. According to them, the best model should have less deviation, i.e, least MSD value and higher Coefficient of efficiency (r_{se}), Residual mass curve coefficient (r_{mcs}) and Square of Correlation(r_{sq}).

TABLE I
COMPARISON TABLE FOR MEASURES OF ACCURACY

Pollutant	MA Length (in months)	MINITAB	Gauch and others	Aitken's eqn		
LOCATION: AMCO BATTERIES						
		MSD	MSD	rsq	rse	rmcs
SO2	12	103.69	103.85	0.518	0.487	0.48
	24	103.07	103.29	0.424	0.421	0.412
	36	91.86	91.57	0.518	0.487	0.48
NOx	12	88.55	88.571	0.279	0.276	0.265
	24	76.02	76.06	0.305	0.305	0.293
	36	79.13	79.17	0.297	0.276	0.265
SPM	12	1816.9	1816.89	0.406	0.398	0.388
	24	1680.13	1679.95	0.406	0.398	0.388
	36	1929.83	1930	0.37	0.309	0.3
LOCATION: GRAPHITE INDIA						
SO2	12	90.02	89.99	0.105	0.1	0.084
	24	81.67	81.63	0.184	0.184	0.169
	36	85.67	85.64	0.229	0.144	0.133
NOx	12	88.78	88.43	0.341	0.324	0.314
	24	70.97	71.66	0.408	0.408	0.398
	36	82.2	81.76	0.341	0.324	0.314
	12	2261.98	2262	0.166	0.143	0.129
SPM	24	2044.12	2044.04	0.166	0.143	0.129
	36	2297.1	2296.76	0.134	0.037	0.024
LOCATION: AR CIRCLE						
SO2	12	163.28	175.31	0.431	0.39	0.168
	24	173.6	182.58	0.405	0.405	0.072
	36	186.3	196.58	0.431	0.39	0.168
NOx	12	199.54	199.55	0.215	0.215	0.202
	24	179.38	179.98	0.215	0.214	0.202
	36	195.74	195.76	0.195	0.145	0.134
SPM	12	3039.89	3595.24	0.367	0.315	0.306
	24	3037.82	3694.52	0.303	0.276	0.264
	36	2789.79	2459.84	0.367	0.315	0.306

The better options for the analysis are identified in the table with bold and italic. As per the statistical analysis (Table I), best fit model is obtained for a moving average of 24 months for most of the models except for AMCO (SO_2-36 month) and AR Circle (SO_2- 12 months and SPM- 36 months).

The correlation between the model and observed values is found to vary from 0.4 to 0.7 for SO_2, 0.45 to 0.65 for NO_x and 0.4 to 0.6 for SPM. About 80% of data is observed to fall within the error band of ±50%. This is supported by the study conducted on 'Dispersion studies for Industrial zones' by Mr.Lokesh[9]. A sample plot is shown in Fig. 6 for AMCO Batteries for best fit model of NO_x.

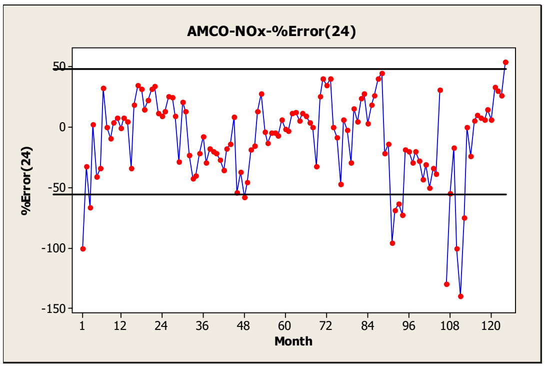


Fig. 6 Time series graph for % error of model values of NO_x for MA 24 months at AMCO Batteries.

After selecting the best fit model from the above said analysis, their ability to forecast is tested with the data acquired between 2004- 07. Fig. 7 shows one such forcast for SPM for MA 24 months at AMCO Batteries. The forecast test for the best fit models showed the same trend as actual values in most of the cases. However, the deviation observed in few cases could be attributed to change in quality of petro products, increase in infrastructure activity in the vicinity, increase in the volume of traffic, introduction of LPG as fuel in many types of automobiles[10], condition of roads, prevailing meteorological conditions, etc.

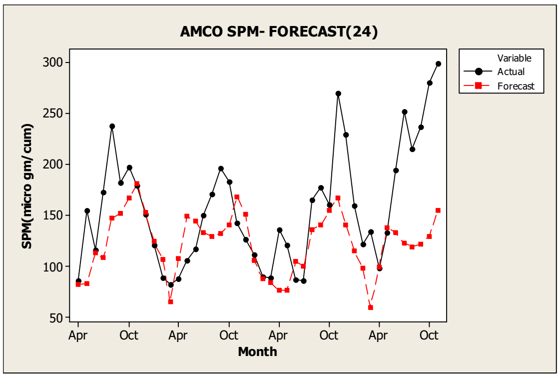


Fig. 7 Time series graph for actual and forecast values of SPM for MA 24 months at AMCO Batteries for the years 04-07.

IV. CONCUSIONS

1. The concentration of Sulphur Dioxide (SO_2) at all locations showed a falling trend due to use of refined petro-products in recent years.

2. The concentration of Oxides of nitrogen (NO_x) showed an increasing trend but was within the permissible limits. The increase may be attributed to increased use of increased use of LPG for vehicles nowadays.

3. The concentration of the Suspended particular matter (SPM) showed the mixed trend. Increase in the volume of vehicles on the roads, infrastructure works are some of the reasons for increase.

4. Best fit model is obtained for a moving average of 24 months for most of the models except for AMCO (SO_2-36 month) and AR Circle (SO_2- 12 months and SPM- 36 months).

5. The correlation between the model and observed values is found to vary from 0.4 to 0.7 for SO_2, 0.45 to 0.65 for NO_x and 0.4 to 0.6 for SPM. About 80% of data is observed to fall within the error band of ±50%.

6. The forecast test for the best fit models showed the same trend as actual values in most of the cases. However, the deviation observed in few cases could be attributed to change in quality of petro products, increase in infrastructure activity in the vicinity, increase in the volume of traffic, introduction of LPG as fuel in many types of automobiles, condition of roads, prevailing meteorological conditions, etc.

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