AIR QUALITY INDEX ESTIMATIONS FROM MEASUREMENTS AND STATISTICAL MODELLING TECHNIQUES OVER DELHI

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ABSTRACT
A study on the annual and seasonal variations of Air Quality Index (AQI) over a period of nine years (1996-2004) based on daily averaged concentration data of criteria air pollutants has been carried out for Delhi. AQI in Delhi for the seven monitoring sites (Nizamuddin, Ashok Vihar, Shahzada Baug, Shahadara, Janakpuri, Sirifort and ITO) were analysed for seasonal and annual trends for these sites. Maximum Operator Function method was used to compute the Air Quality Index and percentage variations in different severity classes discussed which provides in depth analysis of the trends. Analysis showed an improvement in the air quality of sites such as Shahzada Baug, Shahadara, Nizamuddin, Ashok Vihar, Janakpuri, and Sirifort areas and deterioration of the same in the ITO area. The best air quality was depicted by Shahzada Baug followed by Shahdara, both of these were classified as industrial areas. The air quality in other areas have improved slightly in the span of nine years but still remains critical indicating need for continued rigorous efforts in this direction. There is a shift for the worst AQI in the city from winter to summer season in this time span of eight years.

Further, five statistical techniques i.e. Single Exponential Smoothing (SES), Adaptive Response Rate Single Exponential Smoothing (ARRSES), Holt's Linear Method (HLM) ARX (Auto Regressive eXogenous) Model and Auto Regressive Integrated Moving Averages (ARIMA) are adopted for predicting the concentration of the four pollutants i.e. NO_2, SO_2, Suspended Particulate Mater (SPM) and Respirable Suspended Particulate Mater (RSPM). Paired analysis for evaluating the performance of these statistical techniques has been performed for all the four pollutants at ITO. In general, ARIMA technique scores well over the other techniques though it has not been found suitable for predicting the concentration of NO_2.

KEYWORD(S)
Air Quality Index, Criteria air pollutants, Statistical modelling, concentration prediction, ARIMA , performance evaluation.

INTRODUCTION
Air Quality Index (AQI) is one of the popular ways of reporting the daily air quality. It tells us how clean or polluted the air is, and what associated health effects might be a concern for us. Therefore this study estimates the seasonal and annual trends of Air Quality Index using daily observed concentration levels of criteria pollutants. Further, observations are also used for forecasting the daily concentration levels using various statistical techniques.

SEASONAL AND ANNUAL TRENDS OF AIR QUALITY INDEX

AQI estimation based on exceedence factor method as adopted by Central Pollution Control Board (CPCB) in India is used. According to this method, *AQI = Pollutant Concentration / Pollutant Standard Concentration*. In this formula where a factor of 100 as considered in USEPA method is not used. Based on the result, AQI is further categorised as Low, Medium, High and Critical i.e. values less than 0.5 is classified as low, between 0.5 and 1.0 as medium, between 1.0 and 1.5 as high and values above 1.5 as critical. Subsequently maximum operator function is used for AQI analysis.

The daily data of all the seven air monitoring stations of CPCB was procured. Air Quality Index of all the 7 stations for the specified duration (1996 to 2004) was computed using four or eight hourly averaged daily data. For studying the seasonal variation of the AQI values, the break-up of twelve months was taken into consideration as follows. Winter season included December, January and February months, summer season included March, April, May and June months, monsoon season included July, August and September months while post-monsoon included October and November months. Daily AQI calculated based on concentrations of criteria air pollutants at each of the seven stations were used to obtain percentages of occurrences in each of the above mentioned categories on seasonal and annual basis for all the nine years for further analysis.

Overall the following conclusions are drawn from the seasonal and annual analysis of AQI at all the monitoring stations (Mohan and Kandya, 2007):

1. There is improvement in the air quality of the most of the areas during the study period. The best estimated air quality is in Shahzada Baug followed by Shahadara. The next category of stations having somewhat similar and pollution levels are Nizamuddin, Ashok Vihar, Sirifort and Janakpuri where air quality is still critical and continuous efforts are required to further improve the same.
2. ITO showed the worst AQI in the city throughout the study period because of being a busy traffic junction and a thermal power plant not far away from this place. Though worst air quality at ITO was in 2002, there is a gradual improvement till 2004 since then which could be due to traffic decongestion from the construction of new flyovers in the neighbouring areas and commencement of metro rail services in the city. However in absolute terms pollution levels are very high and maximum in the city needing further drastic control measures.
3. There is continuous and significant improvement of air quality at Shahzadabaug and Shahdara from 2002 onwards. Janakpuri, Sirifort and Nizamuddin showed significant improvement in 2003 in comparison to their 2002 levels that again showed deterioration in 2004. However, both ITO and Ashok Vihar showed continuous improvement in 2004 in comparison to their 2002 levels.
4. In 1996, it was generally the winters that used to have the worst type of air quality (4 out of 7 sites) but in 2004, none of the site had winter as the worst season and it is mostly the summers (5 out of 7 sites) followed by post-monsoon that showed the worst type of air quality.
5. Change of season for worst AQI from Winter to Summer in nearly 8 years of span may also be likely due to increased photochemical reactions playing major role with change in the nature of emissions imposed due to different control measures such as CNG in vehicles, more LPG usage in domestic sector etc. calling for a detailed study.

There is also a consistent gradual increase in NO_2 levels from 2001 onwards which again reflects the effect of changed emission patterns in the city and more photochemical reactions. Improvement in Shahdara, Shahzadabaug, Ashok Vihar and ITO specially in in 2004 may be contributed by the traffic decongestion by metro as these sampling stations are closer to metro in comparison to rest of the sites.

6. There is no consistent trend (increase/decrease of AQI) from 2000 onwards at almost all the stations as there are mixed effects of various control measures for example construction of flyovers and metro throughout the city may add to traffic congestion and increased pollution whereas completed metro corridors and flyovers will result into less pollution.
7. Overall, majority of sampling stations showed improvement in AQI from 1996 to 2004. This is the period when regulatory measures were implemented in a major way.

FORECASTING THE CONCENTRATION OF VARIOUS AIR POLLUTANTS

In air pollution problems, the air quality models are used to predict concentrations of one or more species in space and time as related to the dependent variables. They form one of the most important components of an urban air quality management plan (Elsom, 1994, Longhurst et al., 2000). There are two types of mathematical models used in Air Quality Modelling i.e. Deterministic Models and Statistical Models. Deterministic models for air quality assessment are based on the physical and chemical behaviour of pollutants in the atmosphere. These models require several inputs dealing with the emission and meteorology. Statistical techniques do not consider individual physical and chemical processes. A statistical technique is a more pragmatic approach. The processes are ignored and instead tests are done on previous data to look for patterns that can be used for prediction. A deterministic model would probably make the same prediction, but only after a lot of work developing a description of the physics. A statistical approach is about working through the historical data in a general way and finding guides to future behaviour. Because of the simplicity, the statistical models represent an alternative to deterministic models; however, disadvantages include the requirement of long historical data sets and lack of physical interpretation. The statistical models should be developed for each region individually, since their empirical nature does not allow a universal model structure.

In the present study, five statistical techniques i.e. Single Exponential Smoothing (SES), Adaptive Response Rate Single Exponential Smoothing (ARRSES), Holt's Linear Method (HLM), ARX (Auto Regressive eXogenous) Model and Auto Regressive Integrated Moving Averages (ARIMA) are adopted for predicting the concentration of the four pollutants i.e. NO_2, SO_2, Suspended Particulate Mater (SPM) and Respirable Suspended Particulate Mater (RSPM). For evaluating the performance of these statistical techniques performance measures such as Normalized Mean Square Error (NMSE), Root Mean Square Error (RMSE), The Fractional Bias (FB), FAC2 (Factor of 2), Standard Deviation (SD), Geometric Mean Bias (MG), Geometric Mean Variance (VG) and Correlation Coefficient (r) etc. are used.

The salient results of the comprehensive evaluation of the five statistical techniques used for predicting the respective pollutant concentration are as follows.

1. The observations made in the study reveals that ARIMA technique scores well over the other four statistical techniques i.e. SES, ARRSES, HLM and ARX. However, ARIMA is not suitable for predicting the concentration of NO_2.

2. For 7 day prediction both ARIMA and ARX techniques were found suitable.
3. For one day prediction of NO_2, SES method is the most suitable while for 4 day and 7 day predictions, ARX technique is comparatively better than the rest of the four statistical techniques. For predicting RSPM and SO_2 concentration for 1 day, 4 day and 7 day, ARIMA technique is the most suitable statistical technique. For predicting SPM for 1 day and 4 day ARIMA technique is relatively better while for 7 day SPM prediction it is the ARX technique which scores over the other four statistical techniques.
4. The study reveals that SES and ARRSES method *never under-predicts* the concentration of any of the pollutant i.e. NO_2, SO_2, SPM and RSPM i.e. these methods either predict the concentration exactly or over-predict them. The ARX technique *always under-predicts* the pollutant concentration while ARIMA technique *has mixed performance* i.e. its prediction are either ideal or less than expected (under-prediction) or more than expected (over-prediction).

CONCLUSIONS

AQI percentages in different severity class from daily measurements has provided an in-depth analysis of seasonal and annual over nine years (1996-2004) which were marked by drastic policy changes over Delhi. Shazadabaug and Shahdara are found to be least polluted with good AQI. Amongst remaining five sites, Ashok Vihar and Nizamuddin showed the best air quality in the year 2001 while Janakpuri and Sirifort showed best AQI in the year 2003 with ITO in 1999. After having worst AQI in 2002, AQI at ITO has improved in subsequent years. At both, Janakpuri and Sirifort, there is deterioration of AQI in the year 2004.

A shift in worst AQI season from winter to summer is noted and also an increased NO_2 concentration at all sites increased from 2000 onwards. There seems to be change in the nature of pollutants and thereby leading to more photochemical activity with changed regulations and emissions in the city. At certain traffic junctions and locations in the city improvement in air quality is noticed after the introduction of metro rail network.

For predicting the pollutant concentration, ARIMA technique scores well over the other four statistical techniques though it is not suitable for predicting the concentration of NO_2.

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REFERENCES

Manju Mohan and Anurag Kandya, 'An Analysis of the Annual and Seasonal Trends of Air Quality Index of Delhi', International Journal Environmental Monitoring and Assessment (Springer) In press.