To Identify the Most Influential Parameters Responsible for Respirable Suspended Particulate Matter Concentration in Ambient Air

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***Abstract* - Air pollution results from the combination of high pollutant emissions and unfavorable weather. Air quality is strongly dependent on meteorological conditions, and is therefore expected to be affected by long-term changes in weather statistics, i.e., climate change.**

Respirable Suspended Particulate Matter (RSPM) is one of the criteria air pollutants which has crossed limits as suggested by National Ambient Air Quality Standards for most of the cities in India. Increased concentration of RSPM results into adverse effects on human health and the environment.

Meteorological parameters, vehicular emission, industrial activities etc. are the main causes for increased concentration of particulate matter. The effects of each of these parameters vary tremendously across different geographical regions. It is very difficult to collect the data pertaining to all causes responsible for increased concentration. Meteorology plays a vital role in increased concentration of RSPM.

Motivated by the urgent need to understand the correlations between air quality and weather conditions, this study is applied to identify the most influential metrological parameter responsible for RSPM. The study is carried out for Solapur district of Maharashtra state of India. Sensitivity analysis is used as a technique to identify the most influential meteorological parameters responsible for increased RSPM concentration on seasonal basis. Study has identified the influential parameter which matches with the physics.

Keywords- RSPM, Crystal ball, sensitivity analysis.

INTRODUCTION

Air pollutants are added in the atmosphere from variety of sources that change the composition of atmosphere and affect the biotic environment [4]. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emissions. The air pollution concentration vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical conditions. The sources of air pollutants include vehicles, industries, domestic sources and natural sources. Because of the presence of high amount of air pollutants in the ambient air, the health of the population and property is adversely affected [1].

It is necessary to assess the present and anticipated air pollution through continuous air quality survey/monitoring programs. The task of identifying sound air quality management strategies to improve human health and the environment involves a number of scientific, technical, and economic considerations embedded within a social and political context. While lack of full scientific certainty limits our ability to identify optimal policy interventions, research findings on ambient air quality, source apportionment, and health effects can help to guide the development of local, regional and continent wide air pollution management strategies [6]. Policy analysis tools incorporating air quality modeling further support decision-makers in the development and evaluation of air quality management policies by estimating impacts of policies on ambient air quality, health, the environment, and the economy. Of many pollutants, Particulate Matter in recent past has been considered one of the most potent pollutants with regard to its impact on human health [6]. PM with aerodynamic diameter less than 10 μm (PM10), especially the finer particle fraction PM2.5 (particulate matter with aerodynamic diameter less than 2.5 μm), have been shown to be associated with increases in mortality asthma and visibility degradation [7]. Given that PM is emitted into the atmosphere by a number of anthropogenic and natural sources, the physical and chemical patterns may vary considerably. Both natural and anthropogenic emissions supply primary (direct emission of PM) and secondary (formed from gaseous precursors) PM.

Urban population is exposed to high level of air pollutants due to motor vehicle pollution, industrial and domestic sources [2]. It is worldwide phenomena and problem is more acute especially in developing countries because of fast growth rate, slow adaptability of upgrade technology and other socio economical factors [2].

Particulate atmospheric pollution in urban areas is considered to have significant impact on human health. Therefore, the ability to make accurate predictions of particulate ambient concentrations is important to improve public awareness and air quality management. The outcomes of these studies can be used for urban planning and the design and management of transportation of industrial and residential areas

Amid rising concern about public health in industrial towns, the Centre has put on hold the expansion of 43 industrial clusters, including five in Maharashtra, that

have reached alarming and critical levels of pollution. Mumbai, Solapur and Pune cities in Maharashtra have been included for the preparation of the action plans for the control of air pollution for these cities which inter-alia should include the pollution reduction strategies. Mumbai High Court is already seized with the matter regarding air pollution control in Mumbai as per action plan prepared by the State Government. Solapur being a district and the key sources of air pollution relate to vehicles especially to 2 wheelers and a collapsed city bus network. The Environmental Pollution Control Authority (EPCA) reviewed the situation in Solapur and decided to set key deadlines as a strategy to reduce pollution in the city. MPCB (Maharashtra Pollution Control Board) has issued necessary direction to implementing authorities and is following up with them for taking the effective steps for reduction in air pollution in Solapur city. Predictions are possible only when the data pertaining to all causes responsible for RSPM concentration is available. Data collection is a major difficulty. Hence it is necessary to identify the most influential meteorological parameters affecting RSPM concentration on a seasonal basis and use only these parameters for developing a prediction model. This study is directed to identify the most influential meteorological parameter responsible for RSPM concentration of Solapur district on seasonal basis [8].

LITERATURE REVIEW

Influences of Commuting Mode, Air Conditioning Mode and Meteorological Parameters on Fine Particle (PM2.5) Exposure Levels in Traffic Microenvironments, has been studied by Da-Lei Wu, Mang Lin, Chuen-Yu Chan, Wei-Zhong Li, Jun Tao, You-Ping Li,Xue-Fang Sang, Chun-Wei Bu with the aim of determining the impacts of various factors on commuter exposure to fine particulate matter (PM2.5), a series of field studies were carried out to measure commuter exposure to PM2.5 on six major commuting modes (in-cabin mode: bus, taxi and metro; on-roadway mode: walking, bicycle and motorcycle) in a highly industrialized city in the Pearl River Delta, China. The results showed that the exposure level was greatly influenced by the commuter mode, with the on roadway mode showing a higher PM2.5 concentration (76μg/m3). An experiment with the taxi mode suggested that the use of air-conditioning can effectively reduce exposure levels in most cases (by at least 83%). Apart from traffic-related emissions, ambient PM2.5 concentration also had important impacts on exposure levels in most commuting modes, which was further ascertained by the seasonal variations in exposure levels and their significant correlations ($p < 0.05$) with meteorological parameters (temperature, relative humidity, wind speed and direction). The results of a General Linear Model analysis show that temperature, traffic mode and wind speed were significant factors that explained 27.3% of variability for the in cabin mode, while relative humidity and wind speed were the significant determinants for the on-roadway mode, which contributed 14.1% of variability. In addition, wind direction was also an important determinant for both in-cabin and on roadway modes. This study has some valuable implications that can help commuters to adopt appropriate travel behavior to reduce their personal exposure to such pollutants.

The Relationships between Dust Particulates and Meteorological Parameters in Kuala Lumpur and Petaling Jaya, Malaysia has been studied by, Mohamed E. Yassen Universiti Kebangsaan Malaysia, Bangi, Malaysia, This study aims to examine the relationship between dust particulate and selective meteorological variables such as rainfall, relative humidity, temperature and wind speed in Kuala Lumpur and Petaling Jaya, Malaysia, during 1983-1997. Correlation, simple regression and multiple regression techniques have been widely used to model dust concentrations as a function of meteorological conditions. The results reveal that a correlation between dust and rainfall yields reasonable negative relationship, the r- value was ranged from 0.050 to 0.687 and not statistically significant at 0.05 levels. The variation of rainfall, relative humidity, wind speed and temperature on the average explains 46% of dust concentrations. This indicates that about 46% of the dust particulates concentrations are attributed to meteorological parameters.

STUDY AREA AND DATA

Fig 1. Map of Solapur district

Solapur is the fourth largest district in Maharashtra in terms of land area and seventh largest in terms of population. Solapur is famous for textile industries. It has an average elevation of 458 meters. Solapur falls under the category of dry (arid and semiarid) climate. It has big & small scale textile industries which contribute increasing particulate matter. It has lowest rainfall.

Salient features of Solapur are as follows

- Area Total:- 148.86 km^2
- Elevation :- 457 m (1,499 ft)
- Population (2011):- 4,315,527
- Climate :- dry (arid and Semiarid) climate
- Rainfall :- 545 mm

Data for surface meteorological parameters was collected from Indian Meteorological department (IMD). This data include daily average values of temperature difference, relative humidity, wind speed, rainfall and vapor pressure

Data for daily average concentration of RSPM was collected from Maharashtra Pollution control board

(MPCB). Both types of the data (meteorology and pollutant concentrations) are collected for period of Jan 2005-Dec 2010. The sensitivity analysis is performed using software "Crystal-ball".

SENSITIVITY ANALYSIS (SA)

Sensitivity analysis is the method of finding out change in result of model due to change in one of the parameter. Sensitivity analysis can help to determine the parameters which are responsible for the changing model's results. Sensitivity analysis is the study of how the variation (uncertainty) in the output of a statistical model can be attributed to different variations in the inputs of the model or, it is a technique for systematically changing variables in a model to determine the effects of such changes.

To find out concentration of RSPM by observing the changes is meteorological parameter. By carrying out sensitivity analysis using Crystal ball it is found that concentration of RSPM is sensitive to different meteorological parameters on seasonal basis. The results of the study can be used in order to develop RSPM forecasting model which will include only influential parameters responsible for the concentration and thus will economies the model.

CRYSTAL BALL

Oracle Crystal Ball, Fusion Edition, is a user-friendly, graphically oriented forecasting and risk analysis program that takes the uncertainty out of decision-making. Through the power of simulation, Crystal Ball becomes an effective tool in the hands of the decision-maker. You can answer questions such as, "Will we stay under budget if we build this facility?" or, "What are the chances this project will finish on time?" or, "How likely are we to achieve this level of profitability?" With Crystal Ball, you will become more confident, efficient, and accurate decision-maker. In order to develop model using crystal ball create a spreadsheet and run the program and one can get results from Crystal Ball. Through a technique known as Monte Carlo simulation, Crystal Ball forecasts the entire range of results possible for a given situation. It also shows you confidence levels, so you will know the likelihood of any specific event taking place. The basic process for using Crystal Ball, then, is to:

1. Build a spreadsheet model that describes an uncertain situation.
2. Run a simulation on it.
3. Analyze the results.

EXPERIMENTAL WORK

First of all the data is divided into different seasons as summer (February- May), winter (October- January) and monsoon (June-September) as these are the major seasons experienced in Solapur. Then monthly means for five meteorological parameters: Temperature, Relative humidity, Rainfall, Vapour pressure and wind speed were calculated. The minimum, maximum and average for each parameter were calculated for Solapur station for period 2005 to 2010. Also season wise minimum, maximum and average values for these parameters i.e. for month June to September (06-09), October to January (10-01) and February to May (02-05) were calculated.

Fig 2 shows the different steps involved for sensitivity analysis using Crystal-ball.

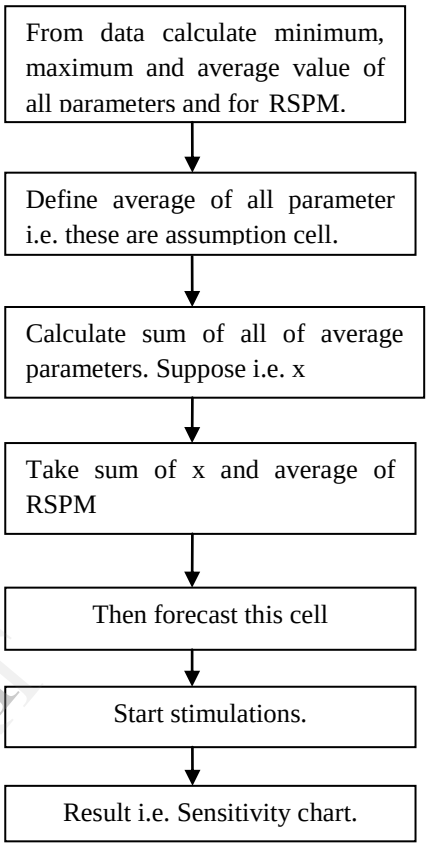

Fig 2. Steps involved in Crystal ball Analysis

RESULT OF SENSITIVITY ANALYSIS

For entire data (2005-2010)

Sensitivity analysis is done for data using crystal ball and following results are obtained-

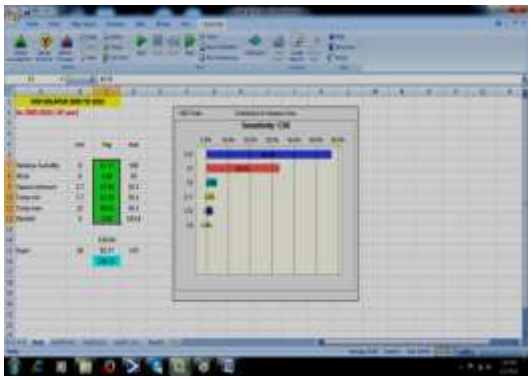

Fig 3. Result of SA of all data from 2005-2010.

For the entire data (2005-2010) RSPM is sensitive for rainfall (C12). It means concentration of RSPM decreases with rainfall. All particles generally settle down by the rainfall so the concentration decreases. Rainfall or

precipitation exerts too fold cleansing action on the pollutants discharged into atmosphere. Thus the result matches with physics behind the process.

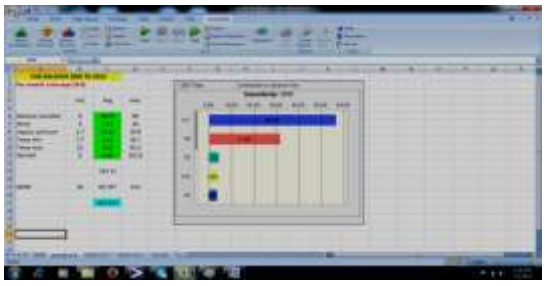

Fig 4. Result of SA of data for Rainy season (Monsoon) June to Sept.(06-09).

For seasons June- September (6-9) RSPM sensitive for rainfall (C11) the conc. of RSPM is decreases because of the rainfall. All particulate matter is settled down by the rainfall so its concentration decreases. Rainfall or precipitation exerts too fold cleansing action on the pollutants discharge into atmosphere. The results are similar to earlier case when entire data was considered for analysis.

Fig 5. Result of SA of data for seasons October to January (10-01)

For winter season October to January (10-01) RSPM is sensitive to rainfall (C10) it means concentration of RSPM decreases because of the rainfall. From the meteorological observations, it was found that there was a rainfall in October and some days in November. All particulate matters settle down by the rainfall so its concentration decreases. Again the result given by software matches with the physics

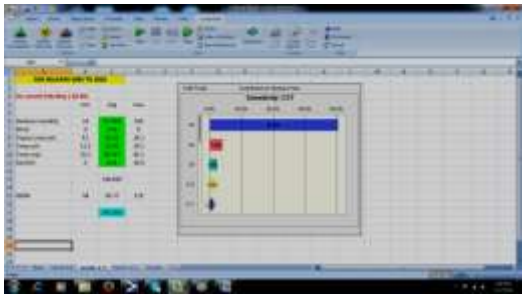

Fig 6. Result of SA of data for summer season Februay to May (02-05).

For summer season February to May (2-5) RSPM is sensitive to relative humidity (C6) the concentration of RSPM increases due to humidity. The moisture content of the atmosphere influences the corrosion action of the air pollutants and indicates the potentiality for fog formation in relation to the degree of air pollution of various means by which humidity may be expressed; relative humidity is most frequently used in air pollution studies.

RSPM concentration increases with humidity i.e. RSPM has positive sensitivity with humidity. This is because due to high humidity it lead to the formation of secondary pollution so pollution level increases and respectively RSPM concentration also increases. (This relative humidity is because of high temperature in that month. General temperature range is 30° to 40°C). And also in this month more particulate matter are in the atmosphere. Thus it tallies with the physics.

The results of the study can be used in order to develop RSPM forecasting model which will include only influential parameters responsible for the concentration and thus will economies the model.

CONCLUSION

Sensitivity analysis is performed in this study so as to identify the most influential parameter responsible for Solapur, which is one of the most polluted districts in Maharashtra state of India.

From the analysis it can be concluded that for all the sensitivity models developed (entire data model and all seasonal model); RSPM is negatively sensitive for rainfall. All particulate matter settles down by the rainfall so its concentration decreases. Rainfall or precipitation exerts too fold cleansing action on the pollutants discharged into atmosphere.

For summer (February- May) RSPM is positively sensitive for relative humidity. The concentration of RSPM increases due to humidity. The moisture content of the atmosphere influences the corrosion action of the air pollutants and indicates the potentiality for fog formation.

FUTURE SCOPE

Result of sensitivity analysis can be used in order to develop an effective RSPM forecasting model for Solapur district on a seasonal basis.

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