MULTIPLE POINT INDUSTRIAL SOURCE COMPLEX – SHORT-TERM PERIOD REGULATORY (MPC –SPR) MODEL: AN OVERVIEW

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ABSTRACT

In order to assess the existing or future ambient Air Quality, the computer aided Air Quality models are considered as an indispensable tool. Though, Air Quality modelling can be arrived by Gaussian and Numerical model, Gaussian model is considered to be the most suitable Air quality model for regulatory application in Indian conditions. Moreover, the Air Quality modelling procedures may be varied from country to country which depends up on their own regulatory permit procedures. In India, the US-EPA preferred AAQ model such as AERMOD and ISCST3 are used for the regulatory purposes. In order to meet the need of developing our own indigenous AAQ model for regulatory purposes, this study has been devoted to develop a Multiple Point industrial source Complex model for regulatory purposes in India.

KEYWORDS: MPC-SPR, AAQ, Regulatory Purpose

NTRODUCTION

The most common model computing the dispersion of air pollution from a single point source is the Gaussian plume model, which was initially proposed by O.G. Sutton (1932). Although the model has its limitations, it is used widely to solve dispersion problems. The process of air pollution modelling includes the four stages (data input, dispersion calculations, deriving concentrations, and analysis) (Visa,*et al.* 2007). The accuracy and uncertainty of each stage must be known and evaluated to ensure a reliable assessment of the significance of any potential adverse effects. The Gaussian-plume models are widely used, well understood, easy to apply, and until more recently have received international approval. The Gaussian-plume models play a major role in the regulatory arena. The Gaussian-plume formula is derived assuming the steady-state conditions. The accurate prediction of GLC of air pollutants, emitted from a point source into the atmosphere in industrial applications, is necessary so as to meet the requirements of governmental regulations. The GLC of the emitted pollutants, generally, are estimated from the Gaussian dispersion model.

Some of the Investigations are reviewed here for the better understanding of the development of Gaussian dispersion model for regulatory applications. Tiwari and Kumar, et al.**(1998)** developed a Gaussian dispersion model for evaluating the increase in air pollution due to proposed cement plant at Kymore and found that the values of SO_2, SPM and NOx are within the limits stipulated by CPCB. An approach to assess air quality assessment of a power plant in the Hongkong–Shenzhen area over coastal complex terrain was described by Jiang *et al,* **(2000)**. They had analyzed regulatory models and an atmospheric dispersion modelling system. Three point sources are integrated; emission rates and emission concentrations are calculated from emission inventory methodologies. Prediction of ground level concentrations of

suspended particulate materials (SPM), sulfur oxides (SOX), nitrogen oxides (NOx) and carbon monoxide (CO) are carried out by Barrat Rod, et al.**(2001)** using Gaussian dispersion equation. The seasonal changes of SPM from Badarpur Thermal station within a distance of 5 km was studied by Goyal and Sidhartha, et al.**(2004)** using a Gaussian plume model. The study was carried out using both monitoring and modelling. Experimental measurements were obtained from a monitoring network in and around the power station. Holmes and Morawska, *et al,***(2006)** reviewed the application of atmospheric models for particle dispersion. The different types of dispersion models, available, outlined and the suitability of the different approaches to dispersion modelling within different environments were assessed.

The main objectives of this study is to develop a computer aided Gaussian dispersion model intended for Air quality regulatory purposes in India.

Gaussian Dispersion Modelling

The prediction of the average concentration of a pollutant from a known emission source having specified emission rate is a critical problem in the pollution dispersion modelling. In fact, such prediction of concentration is not analytically possible since the basic momentum equation governing such dispersion process is highly non-linear. Numerical analysis is inevitable in such a situation considering physical phenomena governing turbulent flow, mixing and transportation processes of airborne species. The departure of winds and other meteorological parameters from quasi-steady state constitutes a source of complexity in atmospheric dispersion calculations

The Gaussian plume equation for a continuous emission source gives the total concentration- C of a gas or particulate matter or aerosol at a ground level location (x, y) by the following expression:

$$C(X,Y) = \frac{Q}{\pi \sigma_y \sigma_z Z u} \times \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_y}\right)^2\right] \times \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad \text{eqn-1}$$

where *C(x,y)* is the ground level concentration ($\mu g/m^3$), *Q* is the uniform pollutant emission rate from the source (g/s), *u* is the stack gas velocity (m/s), σ_y is the dispersion coefficient along the crosswind direction y (m), σ_z is the dispersion coefficient along vertical direction z (m), *x* is the downwind distance (m), *y* is the crosswind distance (m), *z* is the vertical distance (m), *H* is the effective stack height (m). It is assumed that complete reflection of the plume takes place at the earth's surface i.e., there is no atmospheric transformation or deposition at the surface. The concentration C is an average over the time interval equivalent to time interval of estimation of σ_y and σ_z (normally 1-hour). The model calculates the short-term concentrations without consideration of plume history i.e., each 1-hour period is completely independent. Equation (1) is valid for any consistent set of units. However, to account certain atmospheric properties, the basic equation is required to be modified. The most significant modification occurs because of the observed fact that the vertical mixing of the plume tends to be uniform beyond a critical distance downwind. The modified equations are presented below.

$$C = \frac{Q}{\pi \sigma_y \sigma_z Z u} \times \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_y}\right)^2\right] \times \sum_{N=-K}^{N=K} \exp\left[-\frac{1}{2}\left(\frac{H+2NL}{\sigma_z}\right)^2\right] \qquad \text{eqn-2}$$

where

L is the mixing height (m), *K* is the number of pollutant reflections +ve for x>0; -ve forx<0, *N* is the total number of reflections of pollutants. Here the reflection of plume has been considered based on multiple reflections proposed by Bierly and Hewson, et.al.(1962). Theoretically, the number of image plumes will be infinite. However, in practice the

numbers of image plumes are restricted to a finite value by restricting the imaginary height of image sources to a certain level beyond which the contributions from the image plumes to any ground level receptor will, significantly, be small to have any practical consequences. The value of K is limited to a maximum of 4 in order to have a converge of the rapidly infinite series in Eq.(2) above. By using the above equation- 2, the **MPC-SP** model has been developed in C# language for computing the short-term ground level concentrations.

COMPUTATIONAL ALGORITHMS

The features of MPC-SPR are user friendly which provides easy access to all modelling tools and simultaneous visualization of the user's project. The components of the MPC-SPR working window are briefly described below:

The computational program was written in efficient code using 'C#" language. The module is similar to the USEPA ISCST3 and AERMOD model. It aims at preparing data file of hourly meteorological parameters which are similar to the ISCST3 model for computation of ground level concentration (GLC).

This model consists of five pathways. They are Control, Source, Receptor, Meteorology and output pathways. (Please see figure-1). The user provide site information, Averaging time, Options for plume rise equation, Option for urban or rural in the Control pathway. In Source pathway, the information such as Stack Position, internal stack diameter, physical stack height, emission rate, etc., are provided by the user in a separate txt or pdf file. The user provides the either Discrete receptor or grid receptor in the receptor pathway. The meteorology pathway receives information on hourly values of ambient temperature, wind speed, wind direction, stability class and mixing height. The results are stored in designated binary files in the Output pathway to be used for delivering the outputs.

Control Pathway

The control menu is fed with the name of the industry which is to be validated must be and given as an input. The monitoring station for that particular industry is to be specified. Validation study also requires information regarding sampling period and pollutant ID, namely SO_2, NOx, SPM etc., are given as an input to the respective fields (Please see figure-2).

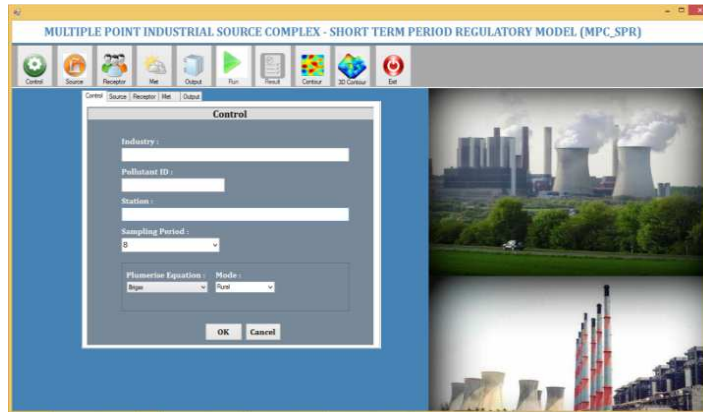**Figure 1: Main Page Showing the Options of MPC-SPR Model**

Figure 2: Main Page Showing the Control Pathway of MPC-SPR Model

Source Pathway

It includes emission inventory. The source oriented Emission data, required for each point source, are the input to the model including of stack positions, stack height, emission rate, stack gas velocity, stack gas temperature, physical stack height and internal stack diameter. Several source groups may be specified in a single run (Please see figure- 3).
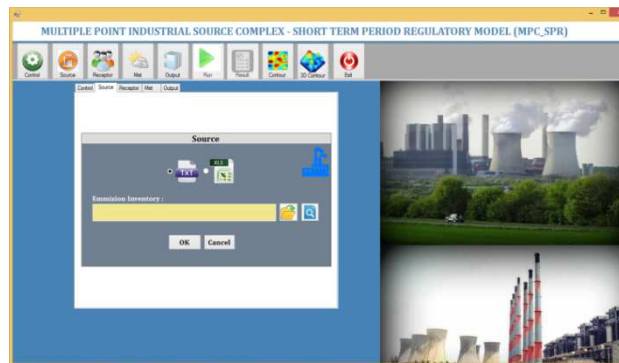

Figure 3: Main Page Showing the Source Pathway of MPC-SPR Model

Receptor Pathway

Receptor pathway admits the single or multiple receptor information with the form of grids which are either discrete receptor (xr, yr and zr) or grid receptor vary from (i x j x k) in a single run using Cartesian grid receptor networks (Please see figure-4).

Figure 4: Main Page Showing the Receptor Pathway of MPC-SPR Model

Meteorological Pathway

Meteorological option includes meteorological input which comprises the Julian day, wind direction, wind speed, atmospheric temperature, the stability class and the mixing/ceiling height. The meteorological data are necessary for running MPC-SPR model. Meteorological data are time – oriented. The model will process all the available meteorological data in the specified input file by default process (Please see figure -6).

Figure 5: Main Page Showing the Meteorological Pathway of MPC-SPR Model

Output Pathway

The file name has been given in the output cell to store the output of the programme. By pressing the "RUN " command button at the bottom, the output is stored in the user specified data file either txt or pdf file format. The file shows the concentration at the selective grid corresponding to the sampling period of the Julian day.

STUDY AREA

Description of Neyveli Lignite Corporation (NLC)

Neyveli Lignite Corporation **(NLC),** an integrated industrial complex, situated in a massive campus of 480 sq. km area houses two Mines, two Thermal Power Stations. This complex is situated at Neyveli, Tamil Nadu, India. Presently, 17 million tonnes of lignite is mined and 2070 MW of power is generated annually. About 1, 29, 200 tonnes of urea and 2,62,000 tonnes of coke are produced per annum.

The Neyveli Lignite Corporation is India's energy-bridge to the 21st century. NLC's growth is sustained and its contribution to India's social and economic development is significant. It is a Public-Sector Enterprise established in 1956, and is situated at Neyveli in Tamil Nadu State, about 200 km south of Chennai.It lies between 11° 28' and 11° 37' latitude and 75° 25' and 79° 33'. Longitude. Figure 5 shows the topographic plan of Neyveli lignite corporation. The existence of extensive lignite deposits in the Neyveli region of Tamil Nadu came to be known in 1870. Detailed exploration of this deposit was carried out in 1943 by the Geological Survey of India (GSI), and based on their finding; the Govt. of India formed the Neyveli Lignite Corporation (NLC) in 1956 for exploration and use of these lignite resources.
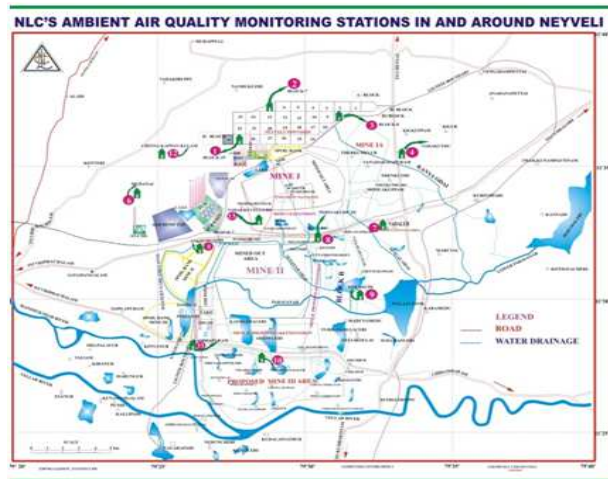
Figure 6: Topographic Plan of Neyveli Lignite Fields

During the last Sixty years, NLC has established three mines at Neyveli and it has commissioned a number of other industrial units. Among them, the major units are Thermal Power Station-I and II.

Thermal Power Station–I (TS-I)

Thermal Power Station-I.The first unit of was synchronized in May 1962 and the last unit in September 1970 consisting of six sets of 50 MW each and three sets of 100 MW each. (Please see figure 5.3). Totally it has power generation capacity of 600 MW.

Thermal Power Station-II (TS-II)

Thermal Power Station consists of 7 sets of 210 MW each. In February 1978, the Government of India sanctioned the Second Thermal Power Station of 630 MW capacity (3 X 210 MW) and in February 1983, the Government of India sanctioned the Second Thermal Power Station Expansion from 630 MW to 1470 MW with an addition of 4 units of 210 MW each. Totally, it has power generation capacity of 1470 MW.

RESULTS

The typical source data used for computing GLC is shown in figure-7.
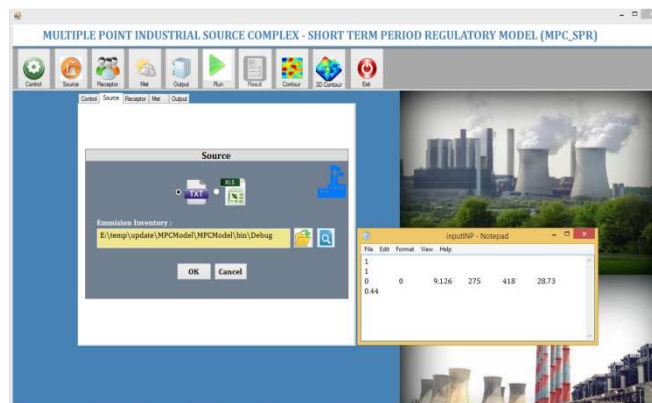
Figure 7: The Page Showing the Source File open View of MPC-SPR Model

Figure 8: Main Page Showing the Receptor Options Page Loading View of MPC-SPR Model
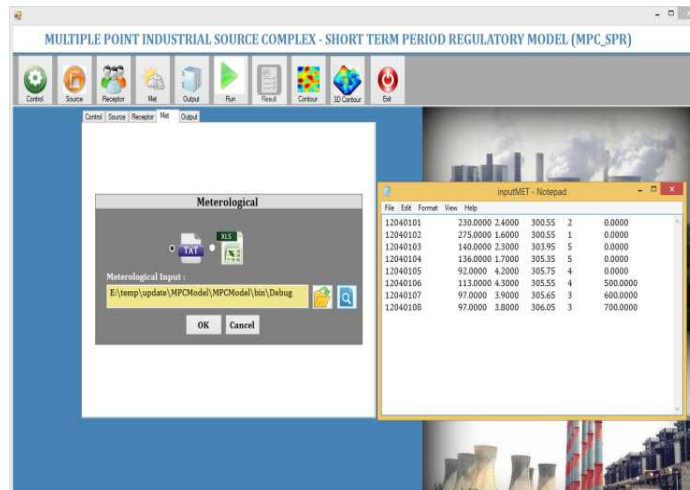

Figure 9: Main Page Showing the Meterological File View Options of MPC-SPR Model

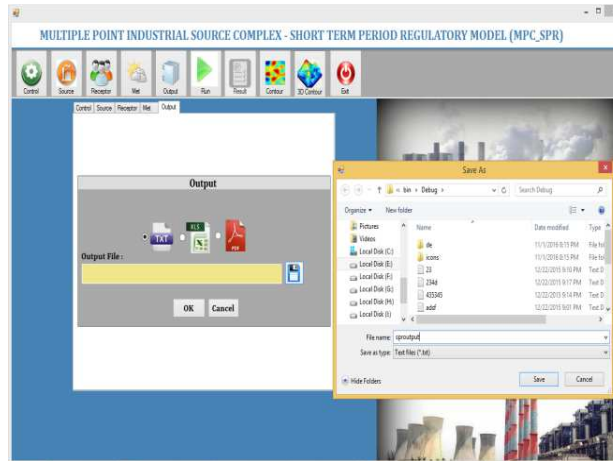**Figure 10: Main Page Showing the Out File save Options of MPC-SPR Model**

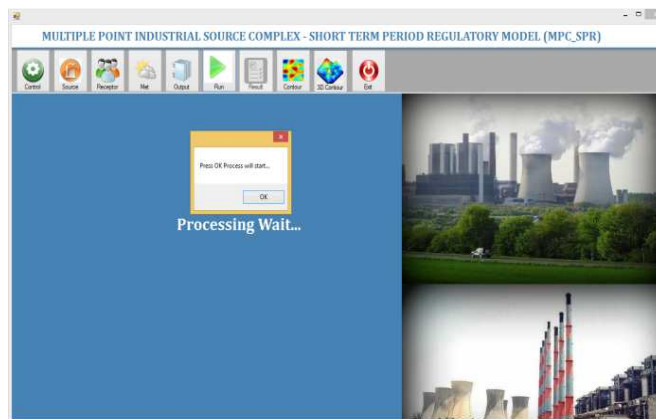**Figure 11: Main Page Showing the Out Put File save Location Options of MPC-SPR Model**

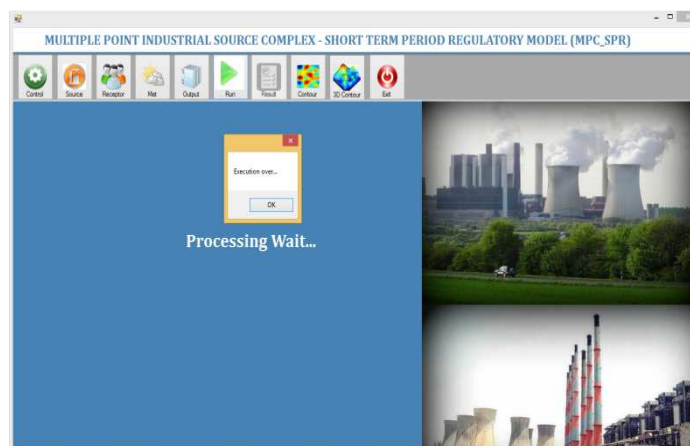**Figure 12: Main Page Showing the Processing Options of MPC-SPR Model**

Figure 13: Main Page Showing the Execution Over Options of MPC-SPR Model
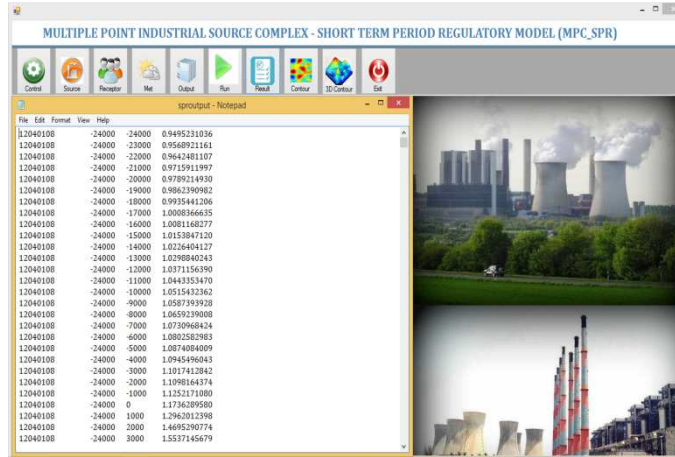
Figure 14: Main Page Showing the Output Text File Options of MPC-SPR Model

Figure 15 Shows the Concentration isopelth of MPC-SPR Model

The **Graphical Output Toolbar** allows the user to easily turn on and off contouring, posting of results, and act as a quick reference to the maximum result value. This toolbar also allows the user to select the desired plot files and output type to be displayed. Please see figure-
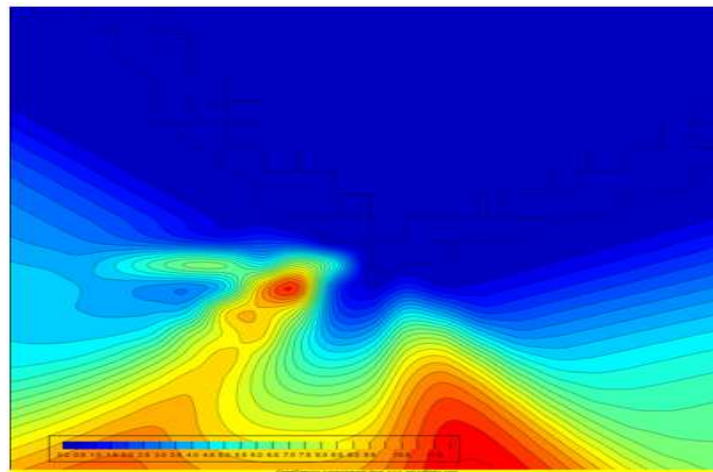

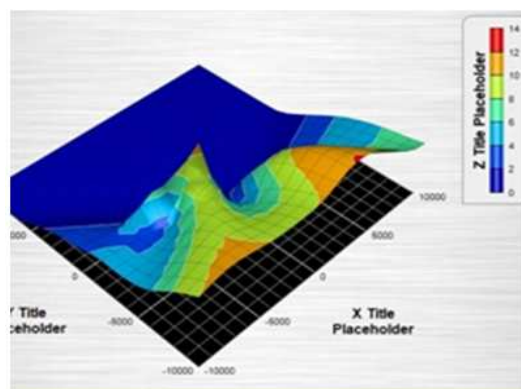**Figure 15: Shows the 2D Concentration Contour of SO$_2$**

Figure 16: Shows the 3D Concentration Contour of SO$_2$

CONCLUSIONS

The MPC-SP model has been developed in C# and run in a Microsoft Visual basic platform. The options are simple to use. Finally, it is recommended for regulatory purposes in India.

ACKNOWLEDGEMENTS

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