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Comparative Study on Multiple Point Industrial Source Complex (MPC) – Short - Term Period And Seasonal Average Period Regulatory Models

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***Abstract*— MOEF requires the industry to prepare environmental statement for assessing impact the proposed by existing industry or proposed industry may have on environment. An important consideration in the preparation of an impact statement is the anticipated effect by the proposed activity will have on air quality since industry having source of major air pollutants. Methods have been developed to predict the air quality impact of an industry through the use of mathematic atmospheric diffusion models. One such a widely used model is Gaussian Dispersion model. Once they are properly validated then they can be used to predict the air quality at short- term as well as long term. This study has been devoted to compare the performance of Multiple Point industrial source Complex- Short-term Period Regulatory and Seasonal average Period Regulatory (MPC-SPeR) Models.**

Keywords—MOEF, MPC- SPR, MPC-SPeR, Gaussian , Model etc.,

INTRODUCTION

Natural air is pure near the place where human habitations have been restricted. Due to industrialization, tons and tons of emissions from large industries such as Thermal Power Stations, Smelting, etc. have been poured into the atmosphere continuously. The atmosphere assimilates the emissions and it tends to be changing its quality day by day. Living beings are alive only if they inhale good quality air. Increasing urban air pollution due to the continuous growth of industries and vehicular traffic has given rise to a need for comprehensive monitoring accompanied by modeling of air quality. It is not always feasible to monitor the concentrations of species at various vulnerable points of a particular area due to high cost and the experimental difficulties involved.

Prediction of pollution levels resulting from a given emission is carried out with the help of air pollution dispersion models which compute atmospheric transport and dispersion of pollutants being emitted into the atmosphere. At present, Gaussian plume model is the most widely used model for predicting air quality from Multiple Point Sources. It describes the dispersion around a single source in an open and homogeneous terrain under steady-state conditions (Benarie et al 1987).

This study has been devoted to compare the performance of Multiple Point industrial source Complex models (MPC-SPR) and (MPC-SPeR).

I. DESCRIPTION OF THE STUDY AREA

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 and this complex is at Neyveli, Tamil Nadu, and India. Presently, 17 million tonnes of lignite is mined and 2070 MW of power is generated. About 1, 29, 200 tonnes of urea and 2,62,000 tonnes of coke are produced per annum. It lies between 11° 28' and 11° 37' latitude and 75° 25' and 79° 33'Longitude. During the last sixty years, NLC has established three mines at Neyveli and it has commissioned a number of other industrial units.

GAUSSIAN SHORT TERM DISPERSION MODEL

In the early 1930s Bosanquet and Peterson derived plume dispersion equations which did not assume a Gaussian distribution. Later Sir Graham Sutton derived pollutant dispersion equation which assumed Gaussian distribution in the vertical and crosswind dispersion of the plume (Sutton, 1947). In the Gaussian method, an instantaneous release of a pollutant from a point source is considered. This pollutant moves downwind in the along wind direction and progressively expands in volume, incorporating air from around it and reducing its concentration. Therefore, the concentration of the effluent is maximum at the point of release, and reduces gradually in both positive and negative directions, thus forming a "Gaussian bell-shaped distribution", as shown in figure below :

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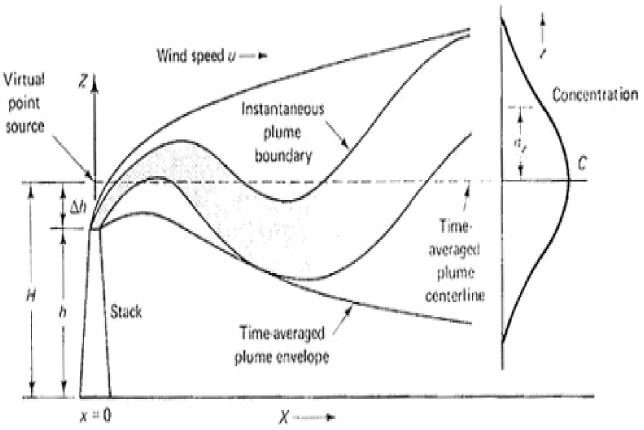

Figure 1 Dispersion of Air Pollutants

Turner D.B (1994) presents the GDE selected for use in the model, which is

$$X = Q/(2\pi u_s \sigma_y \sigma_z) \times \exp\left\{\frac{-y^2}{\sigma y^2}\right\}\left\{\exp\left[-\tfrac{1}{2}((Z_r - h_c)/\sigma_z)^2\right] + \exp\left[-\tfrac{1}{2}((Z_r + h_c)/\sigma_z)^2\right] +\right.$$

$$+ \sum_{N=1}^{k} \exp\left[-\tfrac{1}{2}((Z_r - h_c - 2Nz_i)/\sigma_z)^2\right] + \exp\left[-\tfrac{1}{2}((Z_r + h_c - 2Nz_i)/\sigma_z)^2\right] +$$

$$\left. + \exp\left[-\tfrac{1}{2}((Z_r - h_c + 2Nz_i)/\sigma_z)^2\right] + \exp\left[-\tfrac{1}{2}((Z_r + h_c + 2Nz_i)/\sigma_z)^2\right]\right\}$$

----------- (1)

Where:

X	-concentration (g/m^3)
Q	- emission rate (g/s).
π	- 3.141593.
u_s	- stack height wend speed (m/s)
σ_y	- lateral dispersion parameter (m)
σ_z	- vertical dispersion parameter (m)
z_r	- receptor height above ground (m)
h_c	- plume centerline height (m)
z_i	- mix height (m)
K	- Summation limit for multiple reflection of plume off of the ground and elevated inversion, usually ≤ 4. For stable conditions and / or mixing heights greater than or equal to 1000 m, unlimited mixing is assumed and summation term is assumed as zero

II. GAUSSIAN LONG-TERM DISPERSION MODEL

Over a period of time, the direction of the mean wind shifts. The wind rose, which gives the joint wind speed and direction frequency distribution, is therefore a useful indicator of the characteristic features of the climate of a particular place. To obtain an estimate of the average concentration over a period that is very long compared with that over which the mean wind is completed multiply the integrated concentration formula by the frequency with which the wind flows towards a given sector and divide by the width of that sector at the distance of interest:

$$X_{\text{long-term avg}} = \left(\frac{2}{\pi}\right)^{1/2} \frac{0.01 f Q'}{\sigma_z \overline{U}\left(\frac{2\pi X}{n}\right)} \text{ X}$$

$$\exp\left[\frac{-h^2}{2{\sigma_z}^2}\right]^* \text{ x } \exp\left[\frac{-y^2}{2{\sigma_y}^2}\right] \text{....(2)}$$

Where, the frequency 'f' is expressed in percent, (2πx/n) is the sector width, and Q', σ_z, σ_y, $\overline{U}$ are the average over the long time period. An expression equivalent to this forms on the basis for the calculations by Meade and Pasquill (1958) of annual SO_2 concentration in the vicinity of the staythorp power station.

By using the above equations, -1 and 2, a Computer aided Gaussian Dispersion software named as MPC-SPR and MPC-SPeR models have been developed in C# language and coded in visual basic and work in windows platform for computing the short-term ground level concentrations and seasonal average period concentrations .

III. DEVELOPMENT OF MULTI-PLUME MODEL

The purpose of this work is to develop a Multi-Plume Model for the atmospheric dispersion of pollutants from a number of elevated point sources located in an industrial complex. The Gaussian plume dispersion model is the basic method used to calculate air pollution concentrations from a point source. For a 'pollutant that is chemically inert, it is assumed that the concentration contributions at a receptor from plumes of individual stacks combine additively, so that the plume" may be simply superimposed to obtain the total effect at the receptor location.

In principle the short-term and long term Multi-Plume Model then only involves simple summation or integration over all point sources and for the different meteorological conditions of plume dispersion. The model assumes the well-known simple Gaussian plume and the horizontal and vertical standard deviation functions σ_y, σ_z as functions of downwind distance in the plume and of the stability category. The mean wind speed enters separately into the plume concentration formula, as the concentrations vary inversely with the wind speed

A. *Computer Programme*

The algorithms of the computer programme developed by Palanivelraja.S., (2005) is used to develop the software for calculating the ground–level concentration over an area of m×n sq.km.

B. *MPC Software Development*

After running the 'C#' Programme of Gaussian dispersion equation given in section 2 and 3 to calculate the concentrations on the nodal points successfully, a software package named as Multiple Point industrial source Complex Short-term Period Regulatory (MPC-SPR) Model and Multiple Point industrial source Complex – Seasonal average Period Regulatory (MPC-SPeR) model have been developed in Dot.Net.

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The inputs required for this software package are similar to that of ISCST3 model. The main login page of the MPC-SPR model is shown in Figure 2. In order to evaluate the performance of this model, it has been applied to an industrial complex of Neyveli Air basin .

C. *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 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 are similar to the ISCST3 model for computation of ground level concentration (GLC). This model consist five pathways. They are Control, Source, Receptor, Meteorology and output pathways. Please see Figure-2. 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

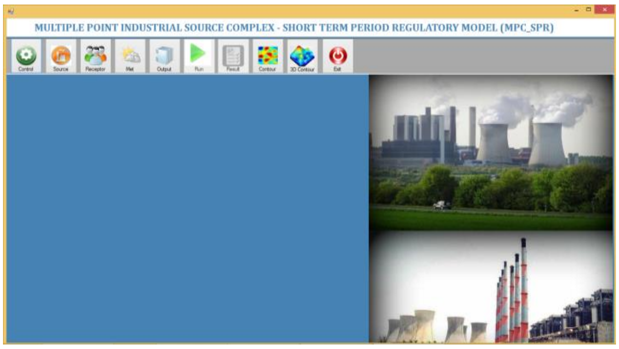

Figure – 2 Main Page Showing the Options of MPC-SPR Model

IV. QUANTITATIVE DATA ANALYSIS

Quantitative data analysis was carried out to verify whether the model's predictions are within a factor of 2 for all the measurements (Turner, 2001). The model's predictions are also compared with observed concentrations and grouped under over prediction, exact prediction and under prediction for assessing their performance. This analysis will be of use for regulatory application to ensure compliance with the air quality standards. The Statistical parameters used for model performance evaluation are given below:

a. *Summary Measures*

$$\overline{O} = \frac{\sum_{i=1}^{n} Oi}{N}$$

$$\overline{P} = \frac{\sum_{i=1}^{n} Pi}{N}$$

$$\sigma_0 = \left[\frac{1}{N}\sum_{i=1}^{n}\left(O_1 - \overline{O}_2\right)\right]^{1/2}$$

$$\sigma_0 = \left[\frac{1}{N}\sum_{i=1}^{n}\left(P_1 - \overline{P}_2\right)\right]^{1/2}$$

b. *Linear Regression*

$$b = \frac{\left[N\sum_{i=1}^{n}\left(O_1Pi\right) - \sum_{i=1}^{n}Oi\sum_{i=1}^{n}Pi\right]^{1/2}}{N\sum_{i=1}^{n}O_i^{\,2} - \sum_{i=1}^{n}\left(O_i\right)^2}$$

A = $\overline{P} - b\overline{O}$

$$\gamma = \left[\frac{N^{-1}\sum_{i=1}^{n}\left(O_1Pi\right) - \overline{O}\,\overline{P}}{\sigma_0\sigma_p}\right]$$

c. *Difference Measures*

MSEs - RMSEs = $N^{-1}\sum_{i=1}^{n}\left[\left(a + bO_i\right) - O_i\right]^2$

MSEu = RMSEu^2= $N^{-1}\sum_{i=1}^{n}\left[P_i - \left(Oa + b_i\right)\right]$

Total MSE = Total RMSE^2 - MSEs + MSEu

d. *Index of Agreement*

$$d = 1 - \frac{\sum_{i=1}^{n}\left(P_i - O_i\right)^2}{\sum_{i=1}^{n}\left(P_i - \overline{O}\,| + |\,O_i - \overline{O}\,|\right)^2}, 0 \le d \ge 1$$

V. EVALUATION OF MODEL PERFORMANCE

Evaluation of an air quality model was based on the accuracy of model predictions as compared to observed concentrations and was done using a computer package developed in Fortran language (Sivacoumar and Thanasekaran, 2001). The package suggests several criteria for evaluating the performance of a model, all of which can be calculated from the observed concentration (Oi) and the predicted values (Pi). Willmott and Wicks (1980) and Willmott (1982b) observed that small differences between observed (O) and predicted (P) concentration will result in negative values of correlation coefficient (γ) which may be misleading while interpreting model performance and recommended the use of index of agreement (d) and root mean square error (RMSE) which indicate the accuracy and error involved in the prediction. For

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a good model the value of d should be close to 1 and RMSE should be close to '0'. In general, the various statistical parameters used for testing model performance are mean, standard deviation, regression analysis and difference measures

VI. PERFORMANCE EVALUATION OF MPC- SPR & MPC-SPeR MODELS

a) Application Of MPC-SPR & MPC-SPeR Model in Neyveli Air Basin

The pollutant modeled is sulpur dioxide. The site is Neyveli. Details of source locations and other site details are discussed below. The data requirements for evaluation analysis consisted of three important parts: the emission inventory, the meteorological data and the air quality data.

b) Emission Inventory

Emission inventory is a database that lists, by source, the amount of air pollutants discharged into the atmosphere during a given time period in a specific geographical area. The study focuses only on the industrial emission sources within the study area. They already have a data base for the inventory of industries for the entire Neyveli. The details of industries located within the study area were obtained from the CARD, Neyveli for this study. The emission source information that needs to be the input into the model is restricted to the physical stack dimensions (height, location, internal diameter), as well as the velocity and temperature of the released gas, and the SO_2 emission rates. The Thermal Power stations include about 12 sources that are responsible for SO_2 generation in the area.

c) Evaluation of MPC-SPR &MPC-SPeR Model

From the observed and predicted mean concentrations for using Briggs equation, it is shown that the predicted mean of MPC-SPR model as 4.361 μg/m^3 is closer to the observed mean 3.824μg/m^3. Regression analysis indicated that the intercept 'a' and slope 'b' are nearer to 0 and 1 for the MPC-SPR model (a=0.26,b=1.07). The comparison of RMSE indicated that there was less error. The index of agreement 'd' indicated that the accuracy of the model was 80%. The results shown that high correlation (r^2 = 0.649) exist between the observed and predicted concentrations. Please see Table - 1

Table 1 Statistical analysis Result for the Model evaluation

Summary measures	
Observed mean	3.824
Predicted mean	4.361
Standard deviation(observed)	2.627
Standard deviation(predicted)	3.493
No of observation	500
Correlation	0.641
Index of Agreement	0.866

From the observed and predicted mean concentrations for using Briggs equation, it is shown that the predicted mean of MPC-SPeR model as 175.57 μg/m^3 is closer to the observed mean 163.94μg/m^3. The comparison of RMSE indicated that there was less error. The index of agreement 'd' indicated that the accuracy of the model was 98%. The results shown that high correlation(r^2 = 0.761) exist between the observed and predicted concentrations. Please see Table - 1

Table 2 Statistical Analysis of MPC-SPR model

S. No.	Statistical parameters	Value
1.	Observed mean	163.94
2.	Predicted mean	175.57
3.	Mean Square Error (MSE)	208.42
4.	Root Mean Square Error (RMSE)	14.436
5.	Index of Agreement (d)	0.985
6.	Correlation Coefficient (r^2)	0.761

CONCLUSIONS

This study, the performance of the models was evaluated separately and their performance was reported distinctively. The statistical analysis reveals that the correlation coefficient (r^2) and index of agreement (d) for MPC-SPR and MPC-SPeR models are 0.64 , 0.866 and 0.76 , 0.98 respectively. Both models performs better agreement between the observed and predicted concentrations, the predictions of MPC-SPeR model is more superior than MPC-SPR model because of its hold higher correlation (r^2=0.76) compared to the MPC-SPR model (r^2 =0.649).

REFERENCES

[1] Benarie, M. M (1987), The limits of air pollution modeling. *Atmospheric Environment, Vol.* 21, pp.1-5.

[2] Eason, B. Noble, and I.N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955. (*references*)

[3] MEADE PJ, PASQUILL F, A study of the average distribution of pollution around Staythorpe, Int J Air Pollut. 1958 Oct;1(1-2):60-70.

[4] Palanivelraja, S, 2005, Development of Computational Algorithms for Multiple Point industrial source Comples (MPC) Model, presented in the AICTE-ISTE sponsored –STTP on Environment Impact Assessment for Thermal Power Station , organised by the Dept of Civil Engg, Annamalai University

[5] Sutton O. G., "A theory of eddy diffusion in the atmosphere", Proc. Roy. Soc. London, A, 135, 1932, pp.143-165.

[6] Turner, D. B., (1994), Atmospheric Dispersion Estimates.