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Comparative Validation of Multiple Point Industrial Source Complex–Short-Term Period (MPC-SPR) and ISCST3 Models in Neyveli Air Basin

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Abstract

MOEF requires the industry to prepare environmental statement for assessing impact that existing 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 is a 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 Dispersing model. Once they are properly validated then they can be used to predict the air quality at any industrial locations. This study has been devoted to develop a Multiple Gaussian diffusion model named as MPC-SPR model and validate the model at Neyveli air basin were large thermal power stations are situated.

Keywords: MOEF, Gaussian, MPC-SPR

INTRODUCTION

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, India. Presently, 17 million tonnes of lignite is mined and 2070 MW of power is generated. About 1, 29, 200 tonnes of urea and 2,62,000tonnes 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. Please see Figure 5.1.It lies between 11° 28' and 11° 37' latitude and 75° 25' and 79° 33'. Longitude. Figure 5.2 shows the topographic plan of Neyveli lignite fields. 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. During the last forty-five years, NLC has established three mines at Neyveli and it has commissioned a number of other industrial units.

MPC – SPR MODEL

The Multiple Point industrial source Complex Short-term Period Regulatory (MPC-SPR) model is an alternate model to US-EPA and it is exclusively developed for regulatory purposes in India. The MPC-SPR model is based on a Gaussian Plume dispersion model from continuous elevated point sources. The pathways considered in the model are similar to ISCST3. They are Control Pathways, Source Pathway, Receptor Pathways, Meteorological Pathways and Output Pathways. This model is designed to use routine surface meteorological information provided by India Meteorological Department (IMD). The power exponent of wend profile depends on the Pasqual stability class and underlying surface characteristics – urban or rural conditions. This model utilizes Briggs dispersion schemes for rural and urban area as a function of downwind distance. The model has been developed in C# and coded in visual basic and work under windows platform with user friendly interfaces. The objective of this study is to evaluate the performance of the MPC-SPR model by comparing the observed AAQ concentrations of SO_2 with the modeled concentrations of SO_2 in Neyveli Air basin.

GAUSSIAN DISPERSION EQUATION

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

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

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

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

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.

By using the above equation, -1, a Computer aided Gaussian Dispersion model named as MPC-SPR model has been developed in C# language and coded in visual basic and work in windows platform for computing the short-term ground level concentrations.

MPC – SPR SOFTWARE DEVELOPMENT

After running the ‘C#’ programme of Gaussian dispersion equation-1to calculate the concentrations on the nodal points successfully, a software package named as Multiple Point Source Complex (MPC-SPR) Model has been developed in Dot.Net. The inputs required for this software package are similar to that of ISCST3 model. In order to evaluate the performance of this model, it has been applied to an industrial complex of Neyveli Air basin.

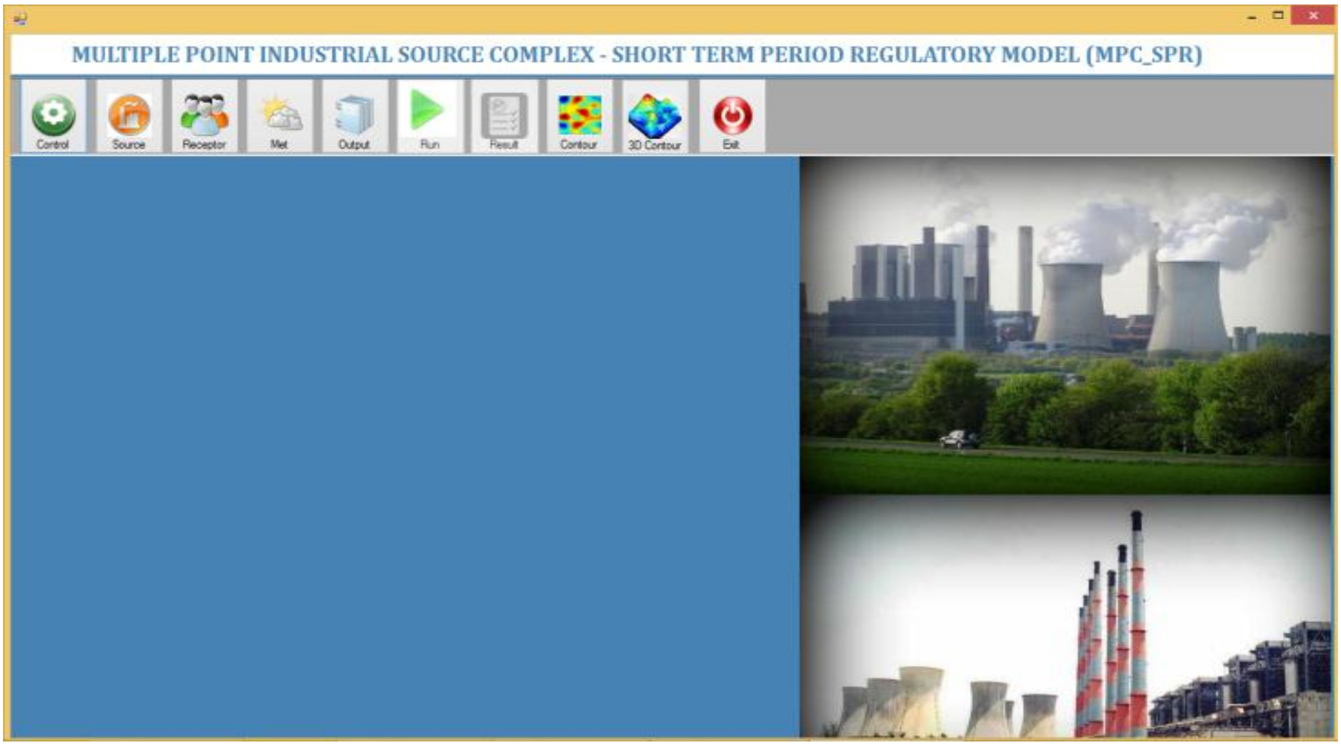

Figure 1: Main Page Showing the Options of MPC-SPR Model

APPLICATION OF MPC-SPR AND ISCST3 MODELS 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.

Emission Inventory

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. 12 Point sources in the Thermal Power stations stacks are responsible for SO_2 generation in the Neyveli area. Table-1 shows the stack coordinate, emission rate, exit stack gas velocity, exit gas temperature, Physical stack height, and Internal stack diameter.

Table 1: Stack characteristics and emission rates of SO_2 from Thermal Power Stations at Neyveli

S.No	Source description	x-coord (m)	y-coord (m)	SO_2 Emission rate (g/sec)	Stack height (m)	Exit stack Temperature ^{0}C	Stack velocity (m/sec)	Stack diameter (m)
1	TS-I							
	UNIT-1	0	0	130	60	150	10.8	5.1
	UNIT-2	-215. 51	0	390	60	150	10.8	5.1
	UNIT-3	-431. 03	0	260	60	150	16.2	5.1
	UNIT-4	-689. 65	0	520	120	150	21.5	5.1
2	TS-II							
	UNIT-1	-3879. 31	-2931. 03	445	170	150	25.0	4.8
	UNIT-2	-3965. 52	-3017. 24	445	170	150	25.0	4.8
	UNIT-3	-4137. 93	-3103. 45	445	170	150	25.0	4.8

Meteorological Data

The model requires the site – specific meteorological information as input data. The local meteorological information that is needed to be input into the model, it is restricted to the Julian day of the year, the average wind flow vector, wind speed, height of the mixing layer, ambient air temperature, and the Pasquill stability category.

Air Quality Monitoring Data

The MPC-SPR and ISCST3 models also requires input information on SO_2 air quality data measured at NLC during the same period. Such information is needed to test the performance of the MPC-SPR and ISCST3 models. The observed SO_2 concentrations were obtained from the short-term air quality survey conducted at 13 AAQ Stations in the neighbourhood of Thermal Power Stations at Neyveli.

Model Validation of ISCST3 at Neyveli

Comparing the modeled concentrations with the measured concentrations always carries out the evaluation of the performance of dispersion models. In this study, the computed results have been compared with the measurements based on 8-hour averages. The ISCST3 model was used for predicting the concentration of the pollutant SO_2 at all the 13 sampling stations. These simulations are carried out for 3 sets of 8-hourly meteorological data, which include various combinations of stability and wind speed, which may be possible during the whole day. The validation result is shown from the Figure- 2 that indicate that the ISC model over predicts the observed concentrations of SO_2.This study believes that the reasons for the over predictions are due to one of the followings:

- By using Pasquill-Gifford dispersion parameters
- It does not account for adjusting the 10 minutes average concentrations to the period longer than the 10-minutes concentration

In order to overcome the over prediction, a computer aieded model was developed and it accounts the factor for adjusting the 10 minutes average to one hour average concentrations.

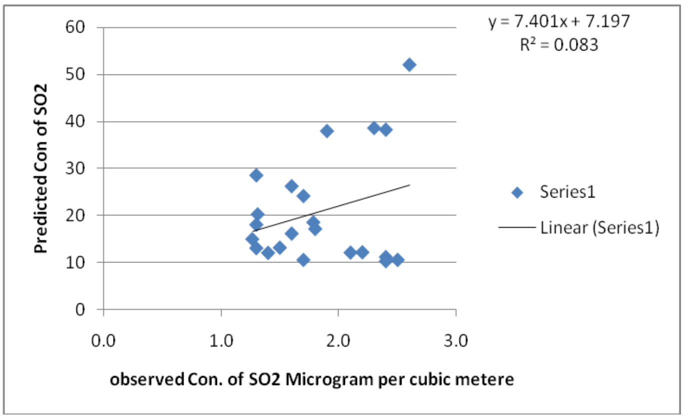

Figure-2: Scatter diagram for Observed Concentration Vs Predicted Concentration of SO_2

PERFORMANCE EVALUATION OF MPC-SPR MODEL

From the observed and predicted mean concentrations for using Briggs equation, it is shown that the predicted mean of MPC-SPR model as 4.361µg/m^3 is closer to the observed mean 3.824µg/m^3. Regression analysis indicates 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 indicates that there is less error. The index of agreement 'd' indicates the accuracy of the model was 86%. Figure -.3 show that the scatter plot of the observed vs predicted concentrations. The results shown that high correlation (r^2 = 0.649) exists between the observed and predicted concentrations.

Table 2: Statistical Analysis Result for the Model Evaluation of Briggs Equation

i) Summary measures

Summary measures	
Observed mean	3.824
Predicted mean	4.361
Standard deviation(observed)	2.627
Standard deviation(predicted)	3.493
No of observation	500

ii) Linear regression

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.264	.164		1.610	.108
	Observed	1.071	.035	.806	30.365	.000
a. Dependent Variable: Briggs						

iii) Difference measures

MSE = 4.598

RMSE = 2.154

Index of agreement :0.8665

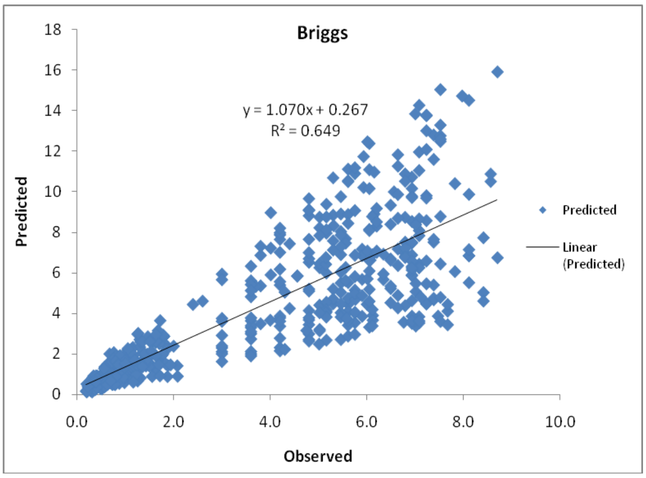

Figure 3: Scatter plots of the observed vs predicted Concentrations

CONCLUSIONS

From the observed and predicted mean concentrations, it is shown that the predicted mean of the MPC-SPR model as 4.361 μg/m^3 is closer to the observed mean 3.824μg/m^3. Regression analysis indicates 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 indicates that there is less error. The index of agreement 'd' indicated that the accuracy of the model is 86%. The statistical analysis shows that the prediction obtained by using Brigg equation in the MPC-SPR model is more realistic. Hence, the model is used for regulatory purpose for the Indian industrial environment.

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