Spatial Pollution Rose Dispersion Pattern (SPR) of SO_2 in the Vicinity of Thermal Power Station At Ennore - Manali Area

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***Abstract*-The purpose of the present study was to describe the pattern of Spatial Pollution dispersion pattern in the neighbourhood of Thermal Power Stations at Ennore – Manali area, near North of Chennai. Ennore-Manali area houses two Thermal Power Stations namely Ennore Thermal Power stations and North Chennai Thermal Power stations. Ennore Thermal power stations is designed to produce electricity at 450 MW capacity (2 x 60 MW ; 3 X 110 MW) using coal as the fuel. North Chennai Thermal power stations is designed to produce electricity at 630 MW capacity (3 x 210 MW) using coal as the fuel. The emission from all the stacks is considered in the Gaussian diffusion equation, for predicting ground level downwind concentrations. The meteorological data gathered for a period of one month is chosen for predictions. This work involves computations and draw the spatial pollution rose pattern of short-term averages of SO_2 Concentrations in the neighbourhood of Ennore – Manali area. The SO_2 isopleths indicated for assessing the most adverse meteorological situations would throw further light on future expansion prospects of Industrial projects at Ennore- Manali area**.

Keywords: Sulphur Dioxide, Spatial Pollution Rose dispersion pattern

I. INTRODUCTION

Industrial air basin, in the contemporary India, experiences a profound change in the nature and extent of air pollution. Factors such as industrial expansion, accelerated consumption of products, fuels and energy, the introduction of new chemical and petrochemical processing industries, the vastly increased use of automobiles and the growth of urbanization, have all greatly increased the varieties and volumes of pollutants thereby presenting new threats to human health, animal health, plant life, property value and the Environment. This is the very reason why this study has been chosen to protect the health and welfare of the public, from the harmful effects of air pollutants.

North Chennai industrial area, has registered a successful and planned expansion of industries during the past five decades. However, a sporadic development of residential colonies has also sprung up in the area. As a result, the magnitude and severity of air pollution problems have attracted the attention of the public. There is a necessity, therefore, to adopt a systematic procedure for controlling quantum of pollutants emitted from each industry located in the area, in order to maintain the ambient air quality in North Chennai area, and in the neighborhoods of the industries at North Chennai area within safe limits. The first step to be initiated, in this relevance, is to conduct another Ambient Air Quality Data in the North Chennai area with the purpose of assessing the presently prevailing air quality. Such an attempt would be helpful to gather data on aspects such as (i) the various industrial sources which emit air pollutants into the atmosphere, (ii) the quantity and nature of emissions discharged by each industry, (iii) the wind turbulence condition that prevails in the area, and (iv) the ambient air concentrations of various pollutants occurring at breathing – level in the area.

II. MODELLING OF AIR POLLUTANT DISPERSION

The Atmospheric dispersion models are simulated mathematically. The physical mechanism and chemistry that are governing the transport, dispersion and transformation of pollutants in the atmosphere are taken into account in the simulation. They are the indispensable tools for prediction of air quality in the ever expanding industrial environments. Several models are available for predicting air quality due to emissions from multiple point sources. When applied for a specific industrial situation and prevailing ambient environmental conditions, performance evaluation of these models is much essential to assess their compatibility and accuracy. The reliability of the model also must be assessed by applying historical meteorology, varying quantities of emissions and measured air quality of the specific industrial environment, with respect to the prevailing wind turbulence and stability conditions of the atmosphere.

In so far as a particular pollutant is concerned, the relationship between the rate of emission of the pollutant discharged through the exit-point of the chimney (stack) and the resulting concentration of the pollutant in atmospheric air at breathing – level is to be evolved. Any Air Quality Survey would offer the necessary data for evolving the relationship between the emission rate and the resulting ambient air concentration of a specific pollutant at any receptor point. This relationship would necessarily take into account the following factors, namely, (i) wind speed and wind direction prevailing in the area, and other meteorological parameters which are relevant to the measurement of the atmospheric turbulence and the atmospheric mixing conditions that are prevailing (ii) the height of the exit-point through which an industrial chimney discharges its emissions, and (iii) the velocity with which the emissions are discharged into the atmosphere through the chimney. (iv) the temperature differential between the hot gases at the time of mixing with the ambient air etc. This attempt, to correlate the pertinent parameters in a cause – effect relationship, for describing the physical mechanism of dilution of pollutants in atmospheric air, is often referred to as 'Modeling of Air Pollutant Dispersion'.

Air pollution control field-operations, as practiced in advanced and industrialized countries, would consist of two steps, namely, Surveillance and Enforcement. The mission of Air Quality Management as a whole is to implement plans that have been adopted to achieve accepted levels of air quality, through the essential steps of Surveillance and Enforcement.

III. NEED FOR THE STUDY

The performance evaluation of USEPA ISCST3 model is found satisfactory as reported by Ganapathy Subramanian. L.R.,(2006) at Manali region in Chennai. However, this study has considered the emission only from one power plant at Manali - Ennore area. Therefore, detailed study is needed for assessing the comprehensive status of the prevailing air pollution scenario in the entire North Chennai Air Basin, so that the comparatively larger emissions of North Chennai Thermal Power Stations could be included in the assessment.

IV. OBJECTIVES OF THE STUDY

The objective of the study is to draw Spatial Pollution Rose dispersion pattern of SO_2 in the neighbourhood of Thermal Power Plants at Ennore and North Chennai, to describe the air quality in North Chennai Air Basin.

V. MATERIALS AND METHOD

The ISC Short-Term Model Algorithms

The ISCST3 model is a steady-state Gaussian plume model, which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex. The following options have been selected for regulatory applications: set the regulatory ''default option''; i.e., use the keyword DFAULT, which automatically selects stack tip downwash, final plume rise, buoyancy induced dispersion (BID), the vertical potential temperature gradient, a treatment for the calms, the appropriate wind profile exponents, the appropriate value for pollutant half-life, and a revised building wake effects algorithm; set the ''rural option'' (use the keyword RURAL) or ''urban option'' (use the keyword URBAN); and set the ''concentration option''.ISCST3 uses Briggs (1969, 1971, 1975) plume rise equations for final rise. The Rural dispersion coefficients from Turner (1970) are used, with no adjustments for surface roughness or averaging time. The Buoyancy induced dispersion (Pasquill, 1976) is included. There are six stability classes used. The Mixing height is accounted for multiple reflections until the vertical plume standard deviation equals 1.6 times the mixing height and the uniform vertical mixing is assumed beyond that point. The Perfect reflection is assumed at the ground.

The Gaussian Equation

The ISC short-term model for stacks uses the steady-state Gaussian plume equation for a continuous elevated source. For each source and each hour, the origin of the source's coordinate system is placed at the ground surface at the base of the stack. The x-axis is positive in the downwind direction, the y-axis is crosswind (normal) to the x-axis and the z-axis extends vertically. The fixed receptor locations are converted to each source's coordinate system for each hourly calculation of concentrations. The hourly concentrations calculated for each source at each receptor are summed up to obtain the total concentrations produced at each receptor point by the combined source emissions. For a steady-state Gaussian plume, the hourly concentration at downwind distance x (meters) and crosswind distance y (meters) is given below.

$$\chi = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right]$$

Where

Q = pollutant emission rate (mass per unit time),

K = a scaling coefficient to convert calculated concentrations to desired units (default value of 1 x 10^6 for Q in g/s and concentration in $\mu g/m^3$),

V = vertical term,

D = decay term, σy, σz = standard deviation of lateral and vertical concentration distribution (m), Us = mean wind speed (m/s) at release height

Equation (1) includes a Vertical Term (V), a Decay Term (D), and dispersion parameters (σy and σz).

VI. DESCRIPTION OF STUDY AREA

The study region, North Chennai air basin is an industrial belt covering an area of about 10 x10 km^2 with a flat terrain located close to Chennai metropolis, India. It houses a major refinery, petrochemical, fertilizer and chemical industries apart from Ennore Thermal Power Station (ETPS) and North Chennai Thermal Power Station (NCTPS) whose stack emissions contribute significantly to air pollution of SO_2.

Figure-1: Description of Study Area.

VII. APPLICATION OF ISCST3 MODEL AT NORTH CHENNAI AIR BASIN

The data requirements for evaluation analysis consist of three important parts: the emission inventory, the meteorological data and the air quality monitoring data.

Emission Inventory

The emission source information that needs to be the input to 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 hourly SO_2 emission rates. NCTPS and ETPS that are responsible for SO_2 generation in the area are considered. Table 1 show the stack co-ordinates, stack height, stack diameter at exit point, emission rate of SO_2, exit stack gas velocity and exit gas temperature. A typical SO_2 emission file for NCTPS stacks has been developed for a period of 28 days.

Table-1. Emission Inventory

Stack Name	Stack Coordinates		Stack Heigt (m)	Stack Inner Dia meter (m)	Emission rate of SO_2 µg/sec
	Lat	Long			
NCTPS Unit 1 (boiler)	13°15.036'N	80°19.727' E	275	4.35	9.126
Unit 2 (boiler	13°15.077'N	80°19.714' E	275	4.35	5.211
Unit 3 (boiler)	13°15.131'N	80°19.737' E	275	4.35	6.966
ETPS Stack 1	13°12.082'N	80°18.708' E	80	4.61	21.924
ETPS Stack 2	13°12.102'N	80°18.661' E	80	4.61	10.746
ETPS Stack 3	13°12.104'N	80°18.641' E	80	4.61	21.78

Meteorological Data

The model requires the site – specific meteorological information as input data .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. The meteorological file for ISCST3 Model has been prepared for 28-days from the meteorological monitoring conducted during a period of 28 days in the North Chennai Air Basin from 1/2/2011 to 28/2/2011. The meteorological monitoring consists of hourly wind speed, wind directions, dry and wet bulb temperatures and cloud cover. The most predominant wind direction during the period was the wind blowing from North. Therefore, this study has chosen the sampling stations, which are all located on the downwind directions. The typical meteorological file developed for the 28 days is considered in this study.

Table - 2: A typical met file format is shown below

Y M D H	WD	UBAR	AMT EM	STB	MIX(R)	
11020101	295.72	2.3000	306.1	1	0.0	
11020102	275.89	2.2800	305.8	1	0.0	
11020103	282.57	2.3600	305.1	1	0.0	
11020104	280.92	2.3300	304.7	1	0.0	
11020105	286.56	2.3500	304.4	1	0.0	
11020106	290.14	2.3800	304.3	1	0.0	
11020107	281.19	2.3800	304.2	1	0.0	
11020108	288.59	2.4300	304.5	1	0.0	
11020109	275.81	2.6200	306.4	2	400.0	
11020070	240.57	2.7500	308.7	2	500.0	
11020071	166.92	2.9100	310.1	2	600.0	
11020072	152.59	2.9100	310.9	2	700.0	
11020073	164.09	2.9100	307.2	2	900.0	
11020074	147.06	2.8900	307.3	2	1200.0	
11020075	146.00	2.9600	307.3	2	1500.0	
11020076	147.44	2.8700	307.1	2	2000.0	
11020077	128.56	2.8000	310.7	1	1800.0	
11020078	075.78	2.7200	309.9	1	1600.0	
11020079	107.16	2.6600	308.7	1	0700.0	
11020120	106.66	2.6600	308.4	1	900.0	
11020121	073.41	2.6100	308.2	1	600.0	
11020122	071.07	2.5900	308.1	1	1400.0	
11020123	130.16	2.5900	308.1	1	0.0	
11020124	261.43	2.3700	307.4	1	0.0	
11020201	281.79	2.2800	306.3	1	0.0	
11020202	275.50	2.2700	305.9	1	0.0	
11020203	278.83	2.2700	305.7	1	0.0	
11020204	283.23	2.3000	305.0	1	0.0	
11020205	281.16	2.2900	304.6	1	400.0	
11020206	278.16	2.2800	304.4	1	500.0	
11020207	286.13	2.3300	304.3	1	600.0	
11020208	281.35	2.3400	304.5	1	700.0	
11020209	284.23	2.4500	306.0	2	900.0	

Air Quality Data

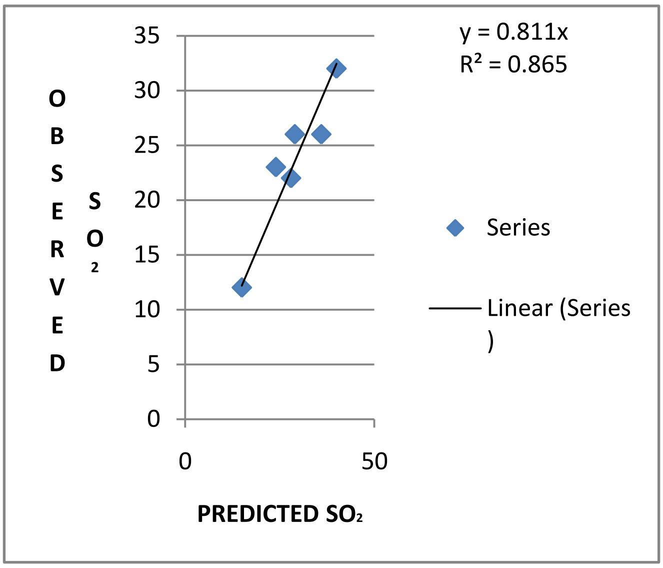
The ISCST3 also requires input information on measured SO_2 air quality data measured at North Chennai Air Basin during the same period. Such information is needed to test the performance of the ISCST3 model. This study has chosen the Ambient Air Quality data from the short-term air quality survey conducted at seven AAQ monitoring stations such as Kattupalli, Athipattu, Minjur, Perungavoor, Manali, Ennore and Kathivakkam in North Chennai Air Basin. An average time of 24-Hours was employed for the measurement of SO_2. All the stacks and air quality station's coordinates (X, Y) were determined by assuming that the X axis is positive to the east of the user-specified origin and the Y axis is positive to the north.

VIII. RESULTS AND DISCUSSION

Meteorologicalformonitoring has been conducted during a period of 28 days from 1/2/2011 to 28/2/2011.The wind rose diagrams have been prepared. SO_2 emission rate has also been worked out and typical values are used in the ISCST3 model. The ground level concentrations (GLC) at the receptor points has been obtained by running the ISCST-3 model, Isopleth plot has been marked on a 25km x 25km grid.

In this study, the computed results have been compared with the observed 24-hour averages. During the period of study, the most predominant wind direction has been from North (N). Hence, this study has chosen seven air quality-monitoring stations such as Kattupalli, Athipattu, Minjur, Perungavoor, Manali, Ennore and Kathivakkam. The ISCST3 model has been used for predicting the concentration of the pollutant SO_2 at the seven sampling stations. These simulations are carried out for 1 set of 24- hourly meteorological data, which include various combinations of stability and wind speed, which may be possible during the whole day.In this Study, the model performance was evaluated by comparing the monthly predicted concentrations of SO_2 obtainedin the model with the measured-concentrations, in the cases of the 3- Continuous Ambient Air Quality Monitoring Stations.

Figure-2 shows scatter–plots for the measured SO_2 concentrations and the predicted SO_2 concentrations in the downwind receptor locations in the ISCST3



model, applicable to North Chennai Air Basin.

Figure-2. Correlation between predicted and measured concentration of SO_2

The results of the statistical analysis of this Study reveals that the value of coefficient of correlation r^2 =0.865 and index agreement d=0.77, which implies that the model performed well.

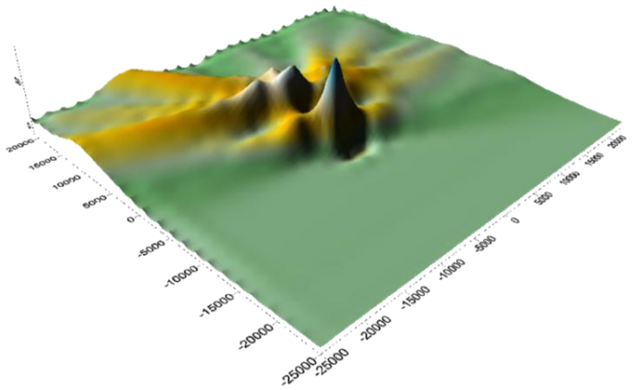


Figure 3:3D Surface View of Spatial Pollution Rose Pattern of SO_2 for the month of February 2011

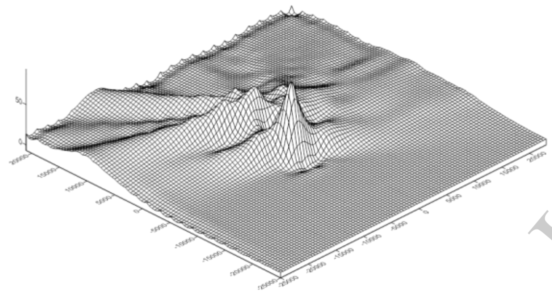


Figure 4:3D Wire Frame View of Spatial Pollution Rose Pattern of SO_2 for the month of February 2011

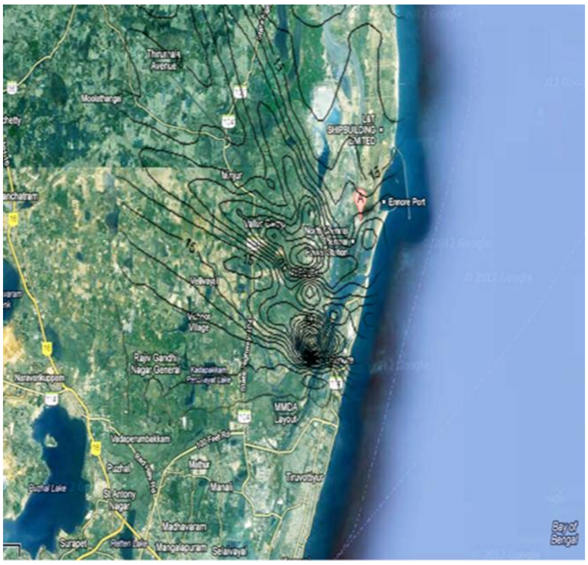


Figure 5:2D View of Spatial Pollution Rose (SPR) Pattern of SO_2 for the Month of February

CONCLUSIONS

In order to study the prevailing metereological potential at Ennore-Manali, a short-term micro meterological monitoring was gathered from 01-02-2011 to 28-02-2011. The concentrations of pollutant namely SO_2, for the months of February, 2011 were plotted using ISCST3 model. From the model prediction it was found that the concentrations of criteria pollutants were below the permissible limits prescribed by Central Pollution Control Board (CPCB). The results were shown that the 8 hour SO_2 concentration well below the Ambient Air Quality Standards. ISCST3 Modeling has been used to simulate the spatial Pollution Rose pattern of SO_2 in North Chennai Air Basin Considering the emissions from North Chennai Thermal Power station (NCTPS) and Ennore Thermal Power Station (ETPS).

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