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Dispersion Modelling of SO_2 Emission from a Coal Fired Thermal Power Plant in Dadri, Uttar Pradesh

G. Praveen Kumar, S. Palanivelraja

Abstract-Ambient air quality management in any industrial area is a prime concern in India. High concentrations of ambient sulfur dioxide (SO_2) in many Indian places are responsible for non-compliance of ambient air quality standards. Dispersion modeling finds an important tool to simulate the ambient air quality of a region and to predict the ground level concentration of SO_2 under various scenarios. National Thermal Power Plant Corporation in Dadri region (NTPC) is chosen in the present investigation for the application of a widely used industrial source complex – short term version 3 (ISCST3) model to predict the ground level concentration of SO_2. Objective of this study is to stimulate the dispersion modeling of SO_2 emission from the coal-fired Thermal Power Plant.

Keywords: Sulphur Dioxide, Spatial Pollution Rose dispersion pattern

I. INTRODUCTION

The United States Clean Air Act of 1970 and its amendments have established National Air Quality Standards to protect man and his total environment from damage by air pollutants (Maynard, 1984). The clean air act produced strong motivation for the application of mathematical models to air quality problems. Indeed the use of models was mandated specifically in the 1977 amendments. As regulatory procedures developed after the passage of these regulations, models have become a major factor in making expensive and important decisions (Maynard, 1984). Increasing pollution levels due to rapid industrialization and urbanization are now causes of major concern in industrializing countries. Air pollution threatens the human health and the gain in economic growth of any country, and planning of air pollution control strategies is therefore essential in order to minimize the harmful effects of the emissions. Air quality management policies are usually developed through a series of processes, which include air quality monitoring, emission inventory preparation and control strategies delineation, and long-term compliance monitoring (Molina and Molina 2004). In order to delineate appropriate air quality management plans, quantification of emissions from different air pollution sources and their impact on ambient air quality becomes essential. Ambient air quality management in any industrial area is a prime concern in India. High concentrations of ambient sulphur dioxide (SO_2) in many Indian places are responsible for non-compliance of ambient air quality standards.

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***** Correspondence Author (s)
G. Praveen Kumar, Research Scholar, Department of Civil Engineering, Faculty of Engineering and Technology, Annamalai University, India.
Dr. S. Palanivelraja, Prof., Department of Civil Engineering, Faculty of Engineering and Technology, Annamalai University, India.

Dispersion modeling finds an important tool to simulate the ambient air quality of a region and to predict the ground level concentration of SO_2 under various scenarios. Air Quality modeling as a planning tool provides a scientific methodology to industries and to the regulatory authority to select the optimum option(s) among various scenarios such as raising stack heights, changing fuels, implementing cleaner production opportunities or installation of wet scrubbers. In establishing ambient air quality standards, regulations, have been introduced in order to set limits on the emissions of pollutants in such a way that they cannot exceed certain prescribed maximum values. As a result of such regulations, it is important that the total mass of emission should be controlled and it is imperative also to know the effects of ambient atmospheric conditions on stack emissions. To achieve this, consideration must be given to mathematical and computer simulation models. Air pollution models constitute a set of formulae that taken into account: source of pollution in a given area, the amounts of pollutants emitted by each source, chemical reaction and transformations, different meteorological conditions, topographical features and other factors that affect dispersion of pollutants. Such models can be used for the calculation of pollutant concentrations at any given point in the area under study. The successful application of all models relies on a detailed emission inventory of all sources and accurate meteorological data applicable to the area, (Scupholome et al., 1977). The air pollution impacts from a coal based Thermal Power Station (TPS) on neighbourhood air quality would depend upon various factors, viz. design capacity, process technology, quality of fuel used for combustion, operation & maintenance of process units and air pollution control equipment installed with the individual process units. The severity of impacts on air environment from any coal power project is also governed by terrain conditions around the project site and the prevailing micrometeorological conditions in the project region. Generally, a coal power project besides the main units like boilers, turbines are also associated with several onsite and offsite facilities, viz. coal yard, conveyor system, coal crusher/pulvirizers, coal handling (loading/unloading) etc. also contribute to air pollution in the form of fugitive emissions. The major air pollutants expected from a TPS are SPM, SO_2, NOx and CO which are emitted continuously from the stacks (point sources) associated with coal combustion boilers. The fugitive emissions of coal dust are also contributed by coal handling activities at storage yard, wind erosion, spillages from conveyor system, pulvirization etc.

The emissions from point sources at TPS are very important for impact assessment as these sources are comparatively large, continuous in nature and are released at higher elevations above ground level. The impacts on air environment from stacks depend on the quality of coal used and can extend to far distances depending on prevailing meteorological conditions. The fugitive emissions are generally less in quantity and it is released relatively closer to ground level which causes impact in the immediate vicinity to very limited distances (about 1-3 km). Amongst the continuous point source emissions, SO_2 and NOx will be of prime concern as they are emitted in large quantity depending on the type of coal used and efficiency of air pollution control equipment. As regards the fugitive emissions, the main pollutant required to be considered is coal dust from different sources.

II. DESCRIPTION OF STUDY AREA

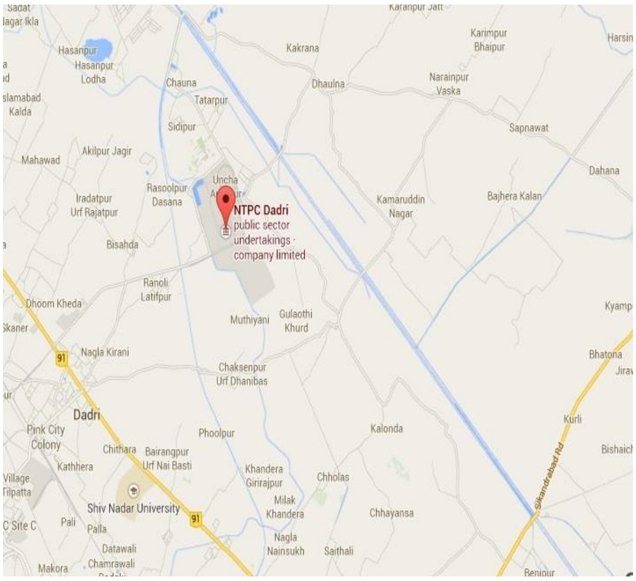

Fig. 1 Description of Study Area

National Thermal power corporation (NTPC), an integrated industrial complex, situated in a massive campus of 500 acres area it houses two stages of coal units and one stage of gas unit in Dadri, uttar Pradesh, India. Stage. 1 coal unit having 4 flues in a single stack and Stage. 2 coal unit having flues in a single stack and Gas units having 4 separate flues and two chemical units Presently, 2.82 lakhs tones of coal is mined and 2637 MW of power is generated. The National Thermal power plant Dadri is India's power project to meet the power demand of national capital region. NTPC Dadri is a unique power plant of NTPC group which has both coal based thermal plant and gas based thermal plant of 1820 MW and 817 MW respectively. NTPC's growth is sustained and its contribution to India's social and economic development is significant. Firstly it was a private sector than in 1989 it became a Public-Sector, and its situated at Dadri in Uttar Pradesh State, about 48 Km away from Delhi . It lies between 28°30' and 28°39' latitude and 77°25' and 79°33'. Longitude. The existence of coal deposits in the Dadri region of Uttar Pradesh came to be known in 1988. Detailed exploration of this deposit was carried out in 1990 by the Geological Survey of India (GSI), and based on their finding; the govt. of India formed the National Thermal Power Corporation at Dadri.

Stage-I Coal Unit

Stage-I Coal unit in which the first unit was synchronized in August 1988 having four flues and each of having capacity of 210 MW (4×210MW). Stage 1 stack diameter is 20 meter at top of RCC shell and stack diameter of each flue is 4.5 meter. The height of stack is 225 meter and stack temperature is 130-150 °C and stack velocity is 20-25 m/s. Emission rate is 256.6654 g/sec.

Stage-II Coal Unit

Stage II coal unit which was synchronized May 2000 having two flues in a single civil structure. And each flue is having capacity 490 MW (2×490MW). Stage 2 stack diameter is 20 meter at top of RCC shell at top and stack diameter of each flue is 7.5 meter. The height of stack is 220 meter and stack temperature is 130-150 °C and stack velocity is 20-25 m/s. Emission rate is 267.6038 g/sec. Also it is having one Gas unit which is having four separate stacks and having capacity of 829MW. The stack diameter is 6.2 meter at top. And height of the stack is 35 meter and also the temperature is between 505-541 ˚C.

III. ORIGIN OF THE PROJECT

National Thermal Power Corporation (NTPC), NTPC Dadri is an unique power plant of NTPC group which has both coal based Thermal Plant and Gas based Thermal Plant of 1820 MW and 817 MW respectively. Therefore, this study is important for simulating the Dispersion pattern of Air pollution in the vicinity of the Thermal Power Plants. In this regard, mathematical models have been recognized as powerful tools to estimate the Ground Level Concentrations more realistically. The objectives of the study are to conduct a short- term 3 months micro- meteorological monitoring in the neighbourhood of NTPC at Dadri. The spatial pollution Rose pattern of SO_2 in the vicinity of NTPC has been stimulated using the observed meteorological data. To check whether or not the mandated ambient air quality standards are being violated.

IV. MATERIALS AND METHOD INDUSTRIAL SOURCE COMPLEX (ISC) MODEL

Mathematical models are used to compute the distribution of pollutant concentrations in air, given the rate and height of emission and the relevant meteorological data. Mathematical models are the basic and very important tools to quality the impacts of existing (or) a proposed project. In this study, the industrial source complex short-term ISCST3 models have been used for estimating short-term concentrations of SO_2. Hence, ISCST3 are the preferred model of USEPA, which have been validated with field data. These models are based on Gaussian dispersion equation which is widely used all over the world. The industrial source complex (ISC) short-term model provides options to model emissions from a wide range of sources that might be present at a typical industrial source complex. The basis of the model is the straight – line on steady state Gaussian Plume equation. The algorithm used to model point source types are described in detail in the following section, (EPA, 1995).

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The Gaussian Equation

The ISC short-term model for stacks uses the steady-state Gaussian plume equation for a continuos elevates 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. Please see fig.3.1. 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 to obtain the total concentration produced at each receptor by the combined source emissions.

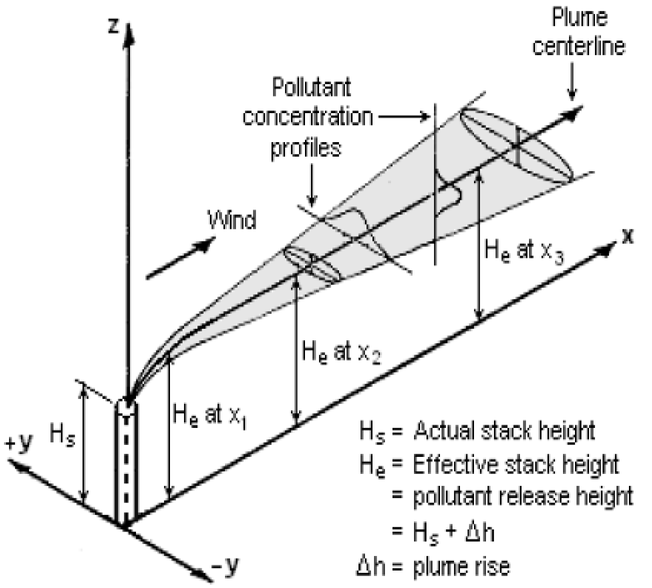

Fig. 2 Gaussian Dispersion Pattern of Air Pollutants

For a steady-state Gaussian plume, the hourly concentration at downwind distance x (meters) and crosswind distance y (meters) is given by:

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

Where,

Q= pollutant emission rate (mass per unit time)

K= scaling coefficient to convert calculated concentrations to desired units (default value of 1 x 106 for Q in g/s and concentration in µg/m3)

V= vertical term

D= decay term

F,Fz= 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 (Fy and Fz).

V. DATA BASE FOR ISCST3 MODEL

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 for ISCST3 Model

The amount of sulphur dioxide emitted from Thermal power plants depends upon the fuel composition. The Stack characteristics and emission rates of SO_2 from Thermal Power plant is shown in Table 1.

Table 1: Stack Characteristics and Emission Rates of SO_2 from National Thermal Power Plant at Dadri

S. No.	Source description	x-coord (m)	y-coord (m)	Stack height (m)	Exit stack temperature ° C	Stack velocity (m/sec)	SO_2 Emission rate (g/sec)
1	STAGE-1						
	FLUE-1	0	0	225	130	20	453.483

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 Dadri Air Basin from 1/2/2014 to 28/2/2014. 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 3 months is considered in this study. The most predominant wind directions during this period of study were from ENE, NE and SSW. The coordinates of the sampling stations are shown in Table 1.

Table 2: A Typical Met File Format is shown below

YMDH	WD	UBAR	AMTEM	STB	MIX(R)
14 0101 01	111.0000	1.6106	297.9	5	000.0
140 10102	110.0000	1.6060	296.1	5	000.0
14 010 103	99.0000	1.5106	296.8	5	000.0
14 010 104	79.0000	1.4106	295.5	5	000.0
14 010 105	57.0000	1.4406	294.4	5	000.0
14 010 106	80.0000	1.3306	294.7	5	000.0
14 010 107	4.0000	1.1806	296.5	2	600.0
14 010 108	75.0000	1.3406	299.5	2	700.0
14 010 109	93.0000	1.2806	288.8	2	800.0
14 010 110	94.0000	1.3706	288.1	2	900.0
14 010 111	94.0000	1.4706	289.0	1	1000.0
14 010 112	108.0000	1.3606	290.0	1	1100.0
14 010 113	112.0000	1.2406	290.5	1	1200.0
14 010 114	112.0000	0.7206	291.0	1	1400.0
14 010 115	113.0000	1.2106	291.0	1	1200.0
14 010 116	111.0000	1.5306	289.5	2	0900.0
14 010117	115.0000	1.3606	301.4	2	0800.0

VI. RESULTS AND DISCUSSION

Comprehensive simulation of the USEPA-ISCST3 model for 1 month short term SO_2 concentrations have been performed in Thermal Power plant at Dadri. The simulation of ISCST3 model has been attempted in the Dadri air basin by applying the ISCST3 model to the meteorology and emissions data.

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Wind Rose Diagram

A short Term ambient air quality and the meteorological data for a period of 1 month has been gathered and used as the data base for the ISCST3 model. The meteorological monitoring consists of hourly wind speed, wind directions, dry and wet bulb temperature and cloud cover. The most predominant wind direction during the period of study has been toward NNE. Wind velocity has varied from 1.3m/sec (0.7 kmph) to 2.5 m/sec (8.6 kmph), and calm (no wind) conditions have prevailed for about 4.7 percent of the time-periods. Cloud cover has varied between 1/8 to 8/8. The dry bulb air temperature has varied from 22.2 degrees Celcius to 27. 2 degrees Celcius. The Relative Humidity has varied from 37% to 96% during the period of study.

Pollution rose of SO_2

This study has representated pollution rose to simulated the dispersion pattern of sulfur dioxide (SO_2) pollution in a city (Dadri) downwind of a large Thermal Power Plant based on data collected from a Power Plant. The pollution rose summarized 8 - hourly SO_2 concentrations at the Dadri Thermal Power Plant. This study concluded that pollution rose based on data collected from Thermal Power Plant can be used to investigate source contributions to air pollution dispersion. Figure 4 and 5 shows the dispersion pattern of SO2 and 2D, 3D view of the dispersion pattern respectively. And also the maximum concentration in February is 94 µg/m3.

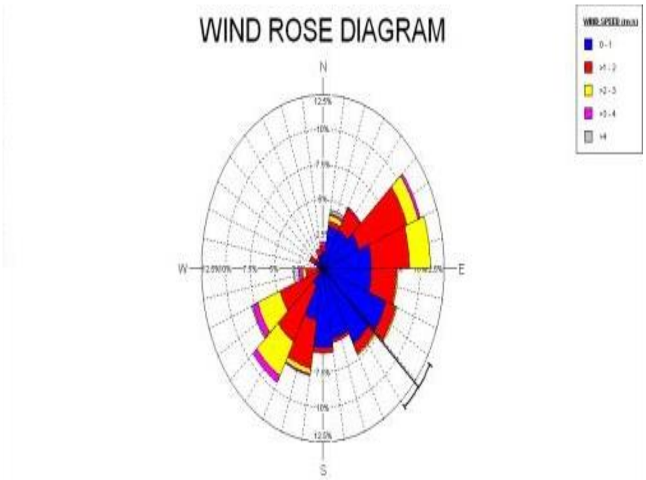

Fig. 3 Wind Rose Diagram for the Month of February

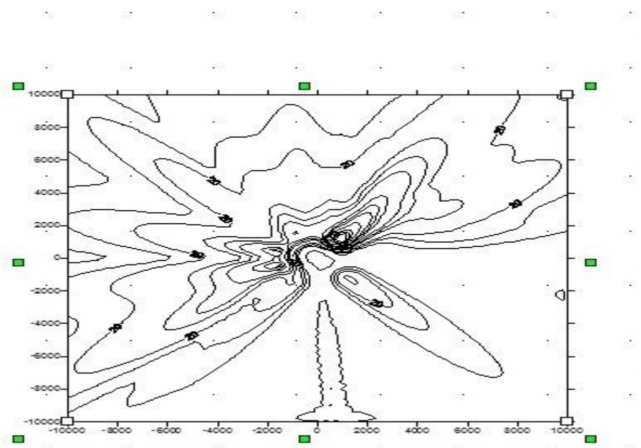

Fig. 4. 2' Dimensional View of the Dispersion Pattern of So_2 for the Month of February

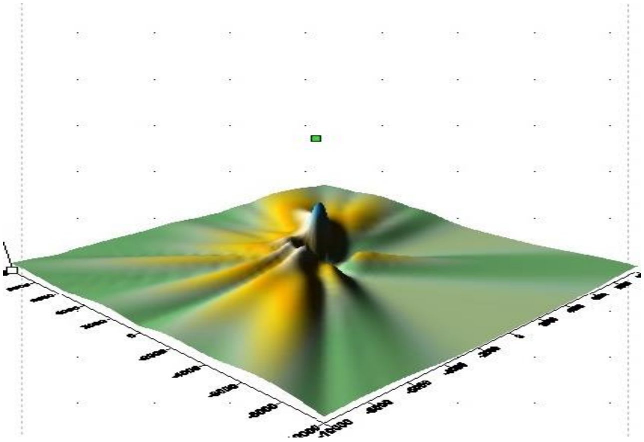

Fig. 5. '3' Dimensional view of the dispersion of So_2 for the month of February

VII. CONCLUSIONS

In order to study the prevailing metereological potential at NTPC Dadri, a short-term micro meterological monitoring was conducted at NTPC Dadri from 01-02-2014 to 28-02-2014. Wind rose diagram was drawn for Dadri location, based on the observed wind data. The most predominant wind direction was east (E). Therefore, pollutants would be transported towards downwind locations along the west (W). The results were shown that the 8 hour SO_2 concentration well below the Ambient Air Quality Standards.

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