Asian Journal of Chemistry; Vol. 29, No. 5 (2017), 1150-1154

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2017.20477

Air Dispersion Model to Study the Point Source Air Pollution and its Impact on Ambient Air Quality

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Received: 27 December 2016; *Accepted*: 18 January 2017; *Published online*: 10 March 2017; AJC-18317

The industrial source complex model is widely used steady-state Gaussian plume model can be used to assess nonreactive pollutant concentrations from a wide variety of source types that are associated with an industrial source complex. The model provides different alternatives for the emissions from different sources including point, area and line sources. It is based on the Gaussian dispersion equations defining the horizontal and vertical distributions of the pollutants by turbulence. This model is the latest version of the regulatory model and assesses pollutant concentrations from wide variety of sources associated with an industrial complex. The study as well as modelling part has been carried out for the period of six months *i.e.* October'2014 to March'2015 in the study area. From the study it has been observed that the maximum resultant concentrations due to incremental ground level incremental concentrations were 67.54, 37.50 and 34.2 μg/m^3 of particulate matter (PM), SO_2 and NO_2, respectively.

Keywords: Ambient air, Dispersion model, Point source, Particulate matter, Sulphur dioxide, Oxides of nitrogen.

INTRODUCTION

Air pollution modeling is a numerical tool used to describe the causal relationship between emissions, meteorology, atmospheric concentrations, deposition and other factors. It plays an important role in science, because of their capability to assess the relative importance of the relevant processes. Air pollution models are the only method which quantifies the deterministic relationship between emissions and concentrations/depositions, including the consequences of past and future scenarios and also the determination of the effectiveness of abatement strategies. Air pollution models are indispensable in regulatory, research and forensic applications. Air pollution measurements give important, quantitative information about ambient concentrations and deposition of air pollutants, but they can only describe air quality with respect to specific locations and times without giving guidance on the identification of the causes of the air quality problems. Air pollution modeling gives a more complete deterministic description of the air quality problems including an analysis of factors and causes (emission sources, meteorological processes and physical and chemical changes) and some guidance on the implementation of mitigation measures [1]. One of the first challenges in the history of air pollution modeling [2,3] was the understanding of the diffusion properties of plumes emitted from large industrial stacks.

Adverse impact of elevated levels of particulate matter in air on human health is evident in many earlier studies [4,5] which show a strong relationship of respiratory and cardiovascular morbidity as well as mortality with finer particles such as PM_{10} [6,7] and $PM_{2.5}$ [8,9]. Gaussian models are based on a set of empirical equations that is mainly applied to coal burning electricity producing plants and to exhaust from automobiles in the cities [10,11]. A number of workers have studied on the ambient air monitoring [12-17] and air quality modeling [18-20] at different industrial areas.

EXPERIMENTAL

In the present study, the sampling was done at three different stacks, the details are given in Table-1. The air quality parameters like particulate matter (PM), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) were monitored and analyzed as per the standard method prescribed by Bureau of Indian Standards shown in the Table-2.

To obtain a representative particulate sample, the sampling was carried out isokinetically, through the sampling nozzle at transverse points. Standard methods were followed during sampling and analysis of different environmental parameters.

TABLE-1
STACK DETAILS WITH LOCATION

Location	Stack height (m)	Location identification
Dryer	40	Stack 1
Stack connected to ESP	90	Stack 2
Stack connected to ESP	108	Stack 3

TABLE-2
EXPERIMENTAL METHODS OF DIFFERENT PARAMETERS

Parameter	Experimental method	BIS Reference
Particulate matter	Gravimetric	IS: 11255 (Part-1) - 1985
Sulphur dioxide	Impinger collection	IS: 11255 (Part-2) - 1985
Oxides of nitrogen	Impinger collection	IS: 11255 (Part-7) - 2005

Samples were collected in every 15 days interval *i.e.* twice in a month for a period of total 6 months.

Particulate matter: Sample for particulate concentration were carried out at the same traverse points where velocity measurements were carried out. Total particulate matter or dust was determined by sampling a measured volume of stack gas through a pre-weighed thimble followed by gravimetric analysis.

$$\text{Particulate matter (mg/Nm}^3) = \frac{(W_f - W_i) \times 10^6}{Q_m \times t}$$

where; W_f = Weight of exposed thimble (g); W_i = Tare weight of thimble (g); Q_m = Actual flow rate (LPM); t = Sampling period in minutes.

Sulphur dioxide: Sulphur dioxide was measured with the help of stack monitoring kit by extracting the gas sample from the sampling point in the stack. It was measured by the barium thorin titration method.

$$C_{SO_2} = \frac{KN(V_t - V_{tb})(V_{soln} / V_a)}{V_{m(std)}}$$

where, K = 32.03 mg SO_2/meq for metric units; N = Normality of barium standard titrant (meq/mL); V_t = Volume of barium standard titrant used for the sample (mL); V_{tb} = Volume of barium standard titrant used for the blank (mL); V_{soln} = Total volume of the solution in which the SO_2 sample is contained, 100 mL; V_a = Volume of the sample aliquote titrated (mL); $V_{m\ (std)}$ = Dry gas volume measured by the DGM, Corrected to standard conditions.

Nitrogen oxides: NOx was also measured with the help of stack monitoring kit. A grab sample was collected in a dilute sulphuric acid and hydrogen peroxide absorbing solution and the nitrogen oxides, except nitrous oxide, are measured calorimetrically using the phenol disulphonic acid (PDS) procedure.

$$C_{NOx} = 2K_cAF$$

where, 2 = 50/25 Aliquot factor; K_c = Spectrophotometer calibration factor; A = Absorbance of the sample; F = Dilution factor.

Micro-meteorology: The meteorological data recorded during the study period is very useful for proper interpretation of the information as well as for input to air quality impact prediction model. On site monitoring was undertaken for various meteorological variables in order to record the site specific data. The meteorological parameters were recorded at the site on hourly basis during the study period consists of parameters like wind speed, wind direction, temperature and rain fall. The maximum and minimum values for these parameters were also considered during the study period. Wind rose diagrams were also plotted to determine the predominant wind direction.

Mathematical modeling: ISC3 model is a popular steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial complex. ISC3 operates in both long-term and short-term modes. In the present study, prediction of impacts on air environment has been carried out by employing ISC3, 1992 dispersion model based on steady state Gaussian Plume dispersion, designed for multiple point sources for short term for all the three air parameters.

Model input data: The location of point source, stack height, diameter, exit velocity, exit temperature, base elevation, wind direction and wind speed and emission rates for each pollutant are used for modeling.

RESULTS AND DISCUSSION

The results of concentrations of the air parameters like particulate matter, SO_2 and NO_x from the three stacks are such as, in stack 1, the particulate matter concentration varies between 87.01 to 110.62 mg/Nm^3, SO_2 between 110.62 to79.18 mg/Nm^3 and NO_x between 19.25 to 32.76 mg/Nm^3. In stack 2, the particulate matter concentration varies between 21.46 to 29.65 mg/Nm^3, SO_2 between 130.42 to 170.01 mg/Nm^3 and NO_x between 32.52 to 65.43 mg/Nm^3. Similarly in stack 3, the particulate matter concentration varies between 19.25 to 29.01 mg/Nm^3, SO_2 between 116.09 to 146.62 mg/Nm^3 and NO_x between 35.18 to 58.46 mg/Nm^3. The above results shows that all the three air quality parameters are almost maintained as per the norms specified by Central Pollution Control Board.

Meteorological study: The meteorological conditions of the study area during the study period were measured. Considering the average wind speed and wind direction of the study area, the overall wind rose diagram was plotted in Fig. 1. The summary of wind pattern during the study period is shown in the Table-3.

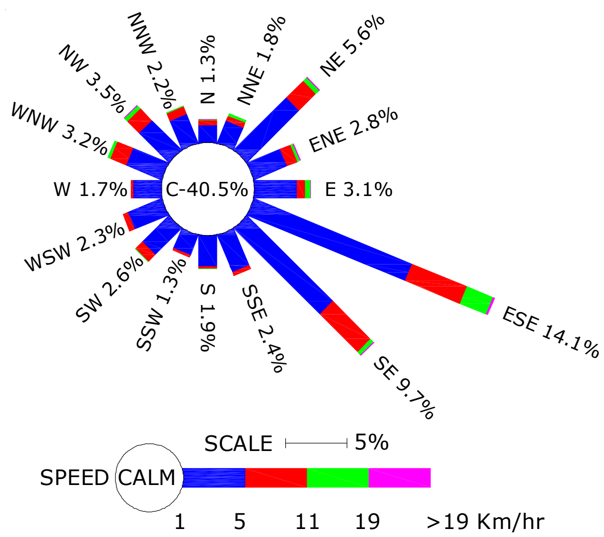

Fig. 1. Wind Rose diagram of the study area

TABLE-3 SUMMARY OF WIND PATTERN DURING THE STUDY PERIOD				
Period	Predominant wind direction		Predominant wind speeds (kmph)	Calm (%)
	First	Second		
October'14 to March'15	ESE [14.1 %]	SE [9.7 %]	1.0 to 5.0 5.0 to 11.0	40.5

During the study period, the average wind flow was in ESE direction as the predominant wind direction and was observed for 14.1 % of the total time. The second predominant wind direction was in SE directions which were observed for 9.7 % of the total time and the calm conditions were observed to be for 40.5 % of the times.

Short term maximum incremental concentrations: Impact predictions of point source on air quality were carried out for the particulate matter, SO_2 and NO_X and the values are tabulated at the Table-4. The corresponding isopleths for pollutants particulate matter, SO_2 and NO_x are presented in Figs. 2-4, respectively. The maximum incremental ground level concentration from the point sources of the plant for particulate matter, SO_2 and NO_x are superimposed on the maximum baseline particulate matter, SO_2 and NO_x concentrations recorded during the period in the downwind direction to arrive at the likely resultant concentrations.

TABLE-4 SHORT TERM MAXIMUM GROUND LEVEL INCREMENTAL CONCENTRATIONS			
Parameters	Incremental concentration (μg/m^3)	Distance (km)	Direction
Particulate matter	1.54	2.2	WNW
SO_2	20.8	2.2	WNW
NO_x	19.9	2.2	WNW

The cumulative concentrations (baseline + incremental) of the plant operations are tabulated below in Table-5.

Conclusions

Gaseous emissions by fuel burning furnace oil (at dryer and in duration) are vented through tall stack of around 40, 90 and 108 m, respectively, for which pollutants usually do not affect to the ground level concentration. Use of low sulphur fuel and optimum stack height of chimney results into low

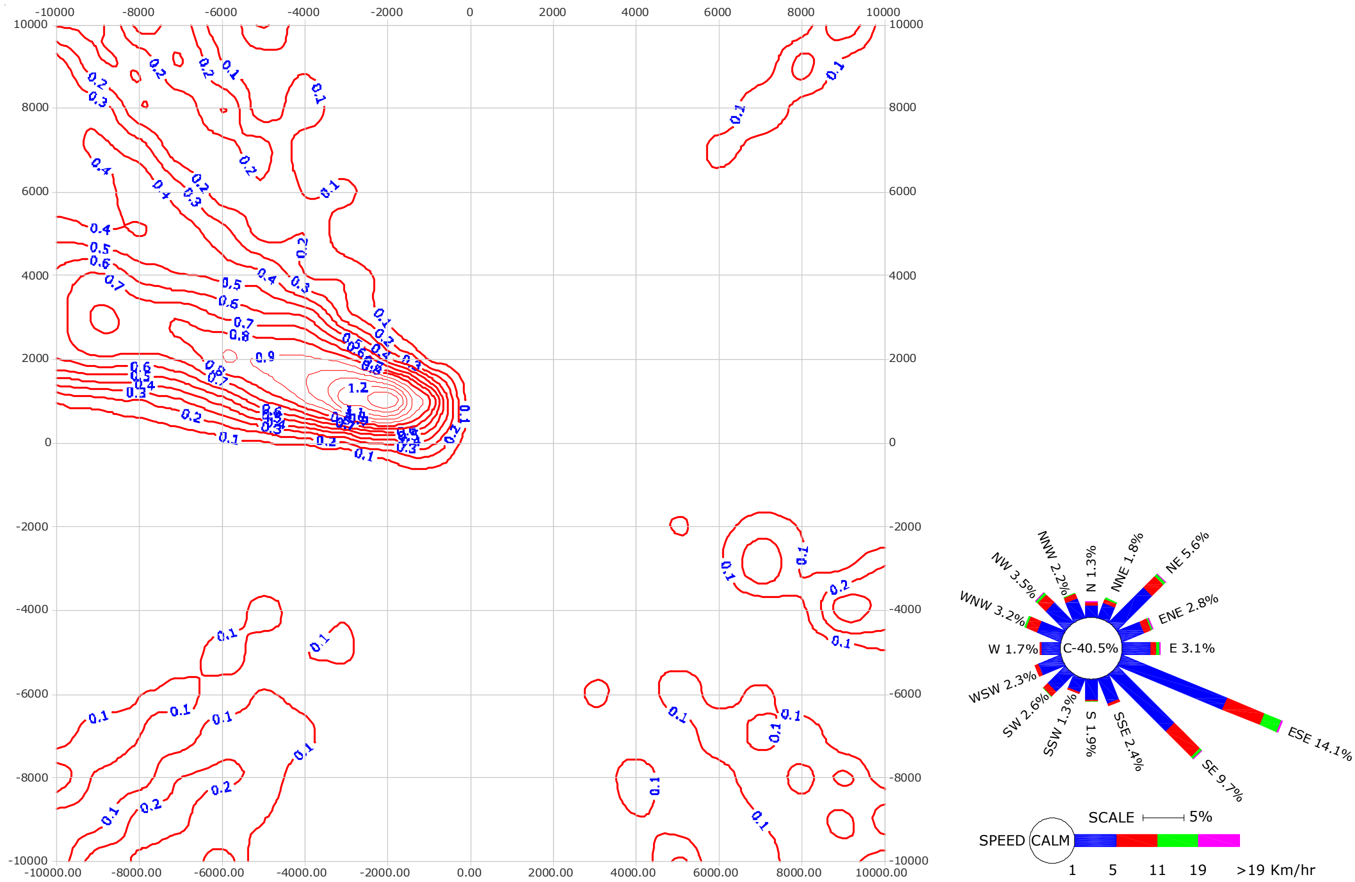

Fig. 2. Short term ground level concentration of particulate matter

TABLE-5 RESULTANT CONCENTRATIONS DUE TO INCREMENTAL GLC'S				
Parameter	Baseline data (μg/m^3)	Maximum predicted incremental values (μg/m^3)	Maximum predicted values (μg/m^3)	Maximum permissible value as per CPCB for residential area (μg/m^3)
Particulate matter	66.0	1.54	67.54	100
SO_2	16.7	20.8	37.5	80
NO_x	14.3	19.9	34.2	80

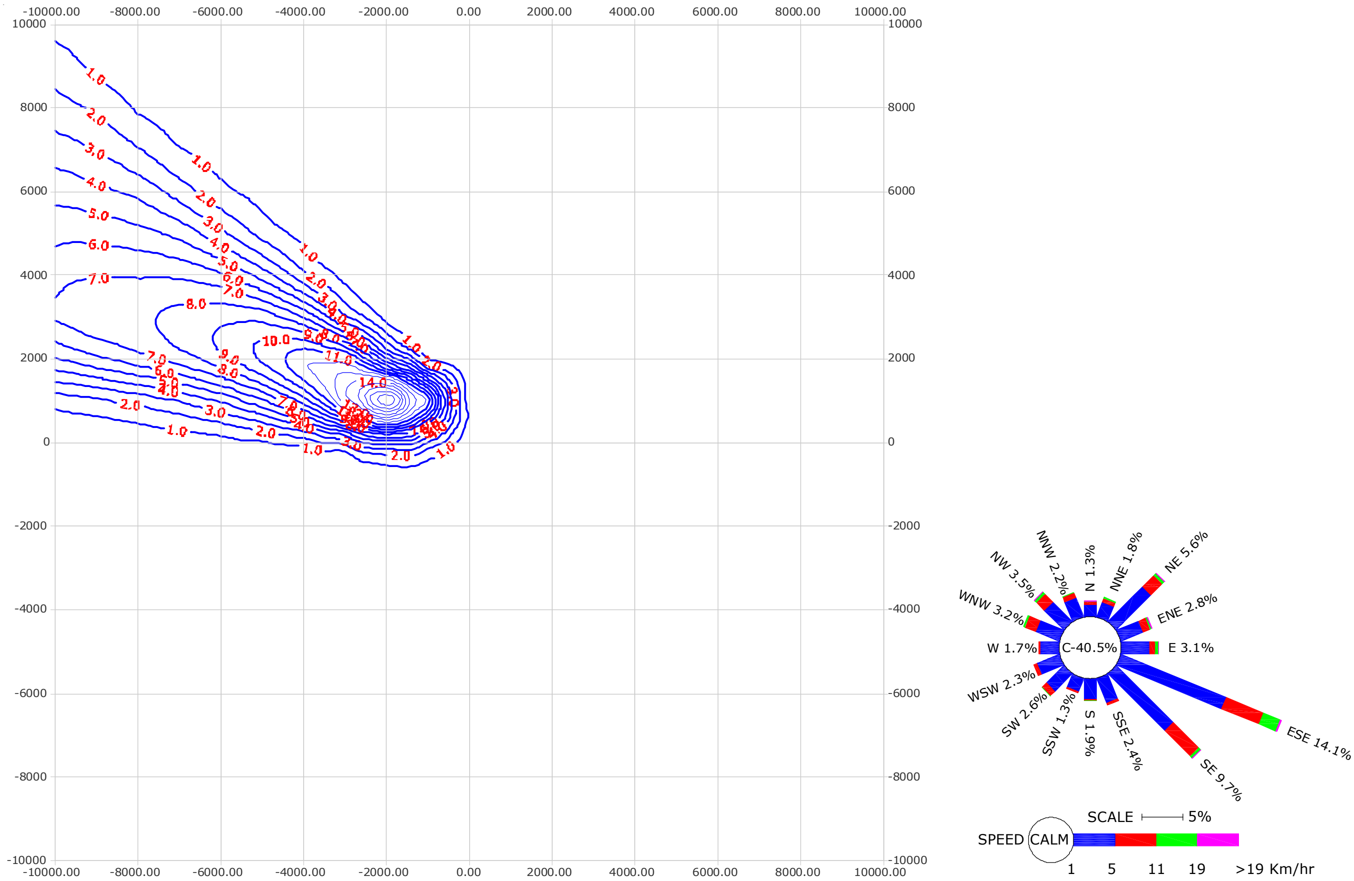

Fig. 3. Short term ground level concentration of SO_2

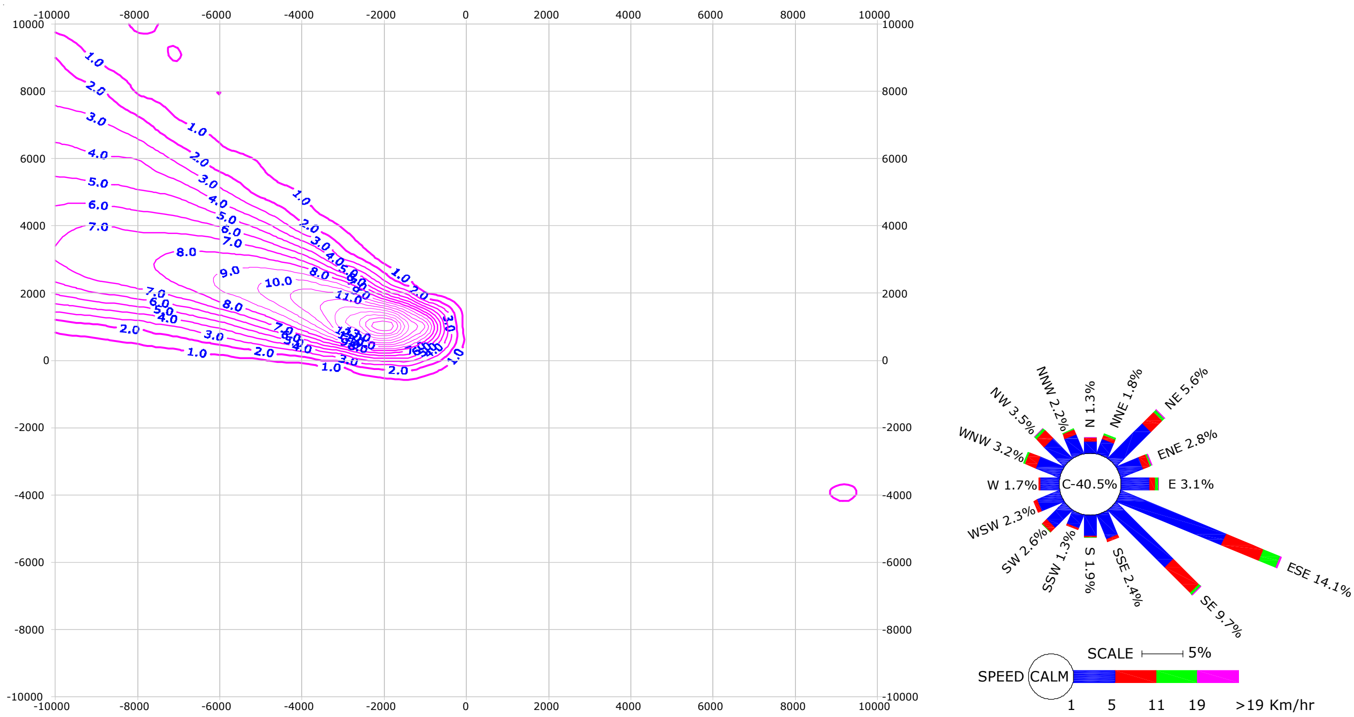

Fig. 4. Short term ground level concentration of NO_x

concentration of these gases in ambient air. Besides, the light behaviour of gases and heavy plantation restrict the gases at ground level nearer the plant.

From air dispersion model, the short term maximum ground level concentrations has shown increments at a distance of 2.2 KM in down wind direction (WNW) for the parameters particulate matter, SO_2 and NO_x. From the observations (Tables 4 and 5), it is evident that the resultant ambient air qualities due to incremental GLCs are within the standards of National Ambient Air Quality (NAAQS)/CPCB.

Study reveals that, there is no such impact of source emissions on ambient air quality in and around the plant premises. Adequate technical control measures taken for environmental management of the plant including installation of high capacity ESP, bag filters, wet scrubbers, dry fog systems, high pressure water sprinklers, mechanized road sweeper, wind screen, development of green belt *etc*. further reduces and arrest the emission of dust and its form to spread over the nearby residential locality. Attempts should be towards reducing the emission further through improvements, so that cumulative effect of pollutants in long run will be maintained.

From the comparisons of standard permissible values and observed readings, it can be concluded that the emissions to air are within acceptable limit and it is evident that all concerned industries has adopted adequate pollution control measures.

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