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Stack Emission Modelling of Foundry Industry

Dr. A. Gandhimathi
Associate Professor, Civil Engineering,
Kumaraguru College of Technology,
Coimbatore, India
gandhimathi.a.ce@kct.ac.in

Vijaya Subramaniam P R
PG Scholar, Environmental Engineering,
Kumaraguru College of Technology,
Coimbatore, India
vijayasubramaniam.18mee@kct.ac.in

Article Info
Volume 83
Page Number: 9886 - 9890
Publication Issue:
May - June 2020

Article History
Article Received*: 19 November 2019*
Revised*: 27 January 2020*
Accepted*: 24 February 2020*
Publication*: 18 May 2020*

Abstract:

Stack emission modelling was done by SCREEN View software for the foundry industry at Malumichampatti, Coimbatore. Emission of suspended particulate matter, Sulphur dioxide, oxides of nitrogen concentration from the stack at ground level at discrete distances was determined by the software. The software uses Gaussian air dispersion model and calculates concentration versus distance from the source. The ambient air quality is measured along the downwind direction from the source of emission. Modeled versus observed comparisons were made at each station point that is at discrete distances. Evaluation of the model was conducted using a statistical method which is R2. The SCREEN View model evaluation showed that there was good agreement between the modeled and observed concentration values. The average R2 value of all pollutants at each station points are 0.75, 0.87, 0.78, 0.86 at a distance of 200m, 500m, 800m, 1000m from the emission source respectively. The ground level concentration of all pollutants at discrete distances from the source is well within the permissible limits as prescribed by Central Pollution Control Board of India. SCREEN View has shown its utility as a suitable model for conducting dispersion modelling from stack emission with a good model skill for estimating ground level concentrations.

Keywords: *Suspended particulate matter, SO2, NOx, Gaussian dispersion model, SCREEN View, Model evaluation.*

I. INTRODUCTION

The introduction of harmful gases and particulates in the atmosphere is air pollution. Substances that create adverse health effects on humans and ecosystem are air pollutants. Due to rapid industrial development and automobile use, the air pollution level in Coimbatore is increased. The environment has an impact on every aspect of human life and every human activity affects the environment with social, technological and economic development (Palanivel, 2003). Automobile emission and industrial emission (foundry units) are the major contributors for emission of pollutants into the atmosphere.

Foundry processes like melting of ferrous, nonferrous metals and reshaping them in to products Recycling of metals is mainly done by foundry industries. Steel, cast-iron and aluminium scrap are casted into new products (Krishnaraj, 2011). The emission of harmful gases and other particulates in the atmosphere through the stack by industrial process in called stack emission. The process of measuring the pollutants emitted from the stack is known as stack emission monitoring. The following tables I and II gives the standards pollutant concentration in ambient air and emission from stationary source respectively.

TABLE I. AMBIENT AIR QUALITY STANDARDS

Area	Concentration (µg/m^3)		
	SPM	SO_2	NO_x
Industrial, Residential, Rural	100	80	80

TABLE II. EMISSION STANDARDS FOR STATIONARY SOURCES

Area	Concentration (µg/m^3)		
	SPM	SO_2	NO_x
Industrial	500	120	120
Residential	200	80	80
Sensitive	100	30	30

The vapour or smoke coming out of the stack is called plume. There are several types of plume behaviour by which the plume disperses into the atmosphere they are, looping, coning, fanning, lofting, fumigation, and trapping plume behaviour. The behaviour of plume mainly depends on the atmospheric stability whether stable, unstable or neutral which is governed by adiabatic and

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environmental lapse rate. There are six types of stability classes, which are defined for different meteorological situations, characterised by wind speed and solar radiation. Solar radiation less than 2.6 kWh/m^2 are classified as low solar radiation while solar radiation between 2.6 - 3 kWh/m^2 is moderate solar radiation and solar radiation greater than 3 kWh/m^2 is high solar radiation. The stability classes are A – very unstable, B – unstable, C – slightly unstable, D – neutral, E – stable, F – very stable.

The purpose of doing this work is that Coimbatore ranked fifth on a list of 50 towns and cities in Kerala, Tamil Nadu, Karnataka and Andhra Pradesh with regard to the amount of particulate matter pollution and ranked third for NO2 pollution, as per the study conducted by the New Delhi based Centre for Science and Environment and also the pollutants have adverse health effects on living beings. The main objective of this work is,

- To monitor the stack emission and quality of ambient air.
- To model the emission from the stack by using SCREEN View software to fine the maximum ground level concentration.
- To compare the observed and predicted concentration values.

A. *Study Area*

The study area is located at Malumichampatti in Coimbatore city, which is the second largest city of Tamil Nadu, India. The boundary map of Malumichampatti is shown in figure 1. In 2011, the population is 16 lakhs and at present 2020 the population is 1.961 million. The population is increased in the last nine years. Malumichampatti, lies on the Coimbatore - Nagapattinam highway (NH83). It is a residential village and the major land use here is agriculture and residential buildings. A foundry industry is also located here along the road side. The entire area behind the foundry industry is occupied by agricultural lands. Coimbatore has around 600 foundries and some are located in SIDCO industrial cluster. Apart from that some foundries are located in residential areas as there are no specific industrialized zones. This particular foundry industry is located in residential area and the surrounding area is occupied by agricultural lands. This study concentrates on the stack emission from the foundry industry at Malumichampatti, as it is one of the residential areas of Coimbatore. Also, no data regarding air pollution is available for this locality for any research purposes.

Fig. 1. Malumichampatti boundary map

II. METHODS AND MATERIALS

A. *Data Collection*

After selection of the study area. The meteorological data have to be collected for the study area. The data to be collected include temperature, wind speed, wind direction, relative humidity, precipitation and the emission rate of each pollutant during the study period. The concentration of each pollutants and the total emission rate is found and then from the concentration values and the total emission rates, the emission rate of each pollutant in found. With the help of collected metrological data, wind rose plot is prepared for the study period to find the predominant wind direction, so that the monitoring stations are selected along the downwind direction. Also, the details of each stack to be monitored and the emission rate of pollutants is collected. The following tables III and IV gives the average value meteorological parameters during the study period and the table gives the details of each stack and the average concentration of pollutants emitted.

TABLE III. METEOROLOGICAL DATA

Parameter	Average values
Temperature (˚C)	28.4
Humidity (%)	74.67
Wind speed (km/h)	7.15
Predominant Wind Direction	W to E
Precipitation (mm)	0
Solar Radiation (kWh/m2)	3.86

TABLE IV. STACK SURVEY DETAILS

Stack No.	Diameter (m)	Height (m)	Average concentration (µg/m^3)

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			SPM	SO_2	NO_x
1	0.6	30.5	22.28	7.58	5.60
2	0.6	30.5	36.46	9.67	6.64
3	0.6	30.5	30.10	7.87	5.15
4	0.3	10	13.61	0.0016	0.0035
5	0.3	10	34.92	0.0051	0.0016
6	0.7	30.5	31.49	0.0038	0.0016
7	0.5	5	36.68	0.0042	0.0009
8	0.2	5	51.49	0.0032	0.0016
9	0.6	5	40.01	0.0018	0.0009
10	0.2	10	59.10	21.09	19.18

B. Sampling

Stack sampling and ambient air quality sampling has to be done. Once after selecting the sampling locations and the required data are collected, sampling is done. Stack sampling is done by Stack Sampler VSS1 to monitor SPM, SO_2, NO_x. Ambient air quality sampling is done by Respirable Dust Sampler APM460 to monitor SPM, SO_2, NO_x. Filter papers are used to collect the particulate samples and absorbing solution are used to collect gaseous pollutants by the sampler. The sampling points to monitor ambient is selected based on the obtained wind rose plot i.e., along the predominant wind direction. Ten stacks in the foundry industry are considered as an area source and monitored for stack emission.

C. Software

WRPLOT View is wind rose plot software given by EPA is used to find the predominant wind direction. SCREEN View software is used to find the ground level concentration of pollutants from emission source.

D. Modelling

The SCREEN View software does the modelling by following the sequence. The input data are specified first and once the inputs are fed, the software processes the data and gives the output in the form of graph (Distance vs Concentration). SCREEN View uses Gaussian model of air dispersion. Gaussian dispersion equation is given by,

$$C(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left\{\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right\} \quad (1)$$

where, C – concentration of pollution, Q – pollutant emission rate, u – horizontal wind velocity, H – height of emission plume center line, σ_y, σ_z – are horizontal and vertical standard deviation of emission, z – emission height of plume form point of emission. To find the concentration at the ground level, eqn.1 is modified as,

$$C(x,y,0) = \frac{Q}{\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y^2} - \frac{H^2}{2\sigma_z^2}\right) \quad (2)$$

Finally, analyzing is done on the output data.

E. Model Evaluation

Evaluation of the model is done by statistical method that include R^2. By comparing the R^2 values of both observed and predicted concentration values we come to know how good the model is. If $R^2 < 0.5$ this value is generally considered a weak and if $R^2 > 0.5$ this value is generally considered strong effect size. Also, we can come to a conclusion whether or not the model is suitable for air dispersion modelling.

III. Result and Discussion

A. Wind Rose Plot

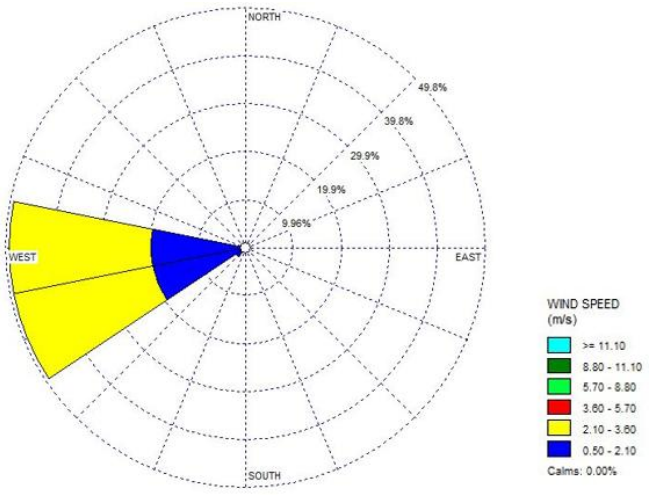

Fig. 2. Wind rose plot

From figure 2, As a known fact that the wind speed and direction play a vital role in air pollutant dispersion and also from wind rose diagram the majority of the wind blows from western to eastern direction, the emission form the stack is blown towards eastern direction. So, the station points to monitor the ambient is selected at discrete distances (200m, 500m, 800m, 1000m) along the eastern direction from the source of emission. The following figure 3 shows the downwind direction of wind.

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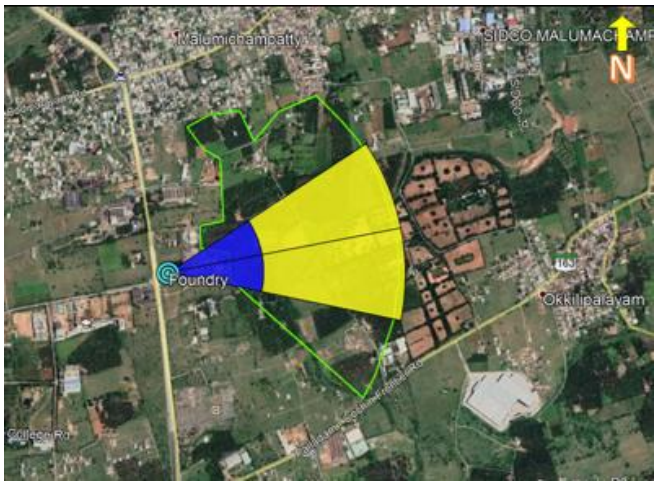

Fig. 3. Downwind direction from emission source

B. *Observed and Predicted Concentration Values*

TABLE V. METEOROLOGICAL DATA

Pollutant		Distance in meter			
		200	**500**	**800**	**1000**
SPM ($\mu g/m^3$)	Predicted	61.55	176.35	138.90	113.55
	Observed	57.13	167.27	124.85	89.57
SO_2 ($\mu g/m^3$)	Predicted	9.02	25.87	20.74	16.38
	Observed	6.68	19.40	13.17	10.32
NO_x ($\mu g/m^3$)	Predicted	6.59	18.92	14.89	11.84
	Observed	394	14.34	9.32	6.09

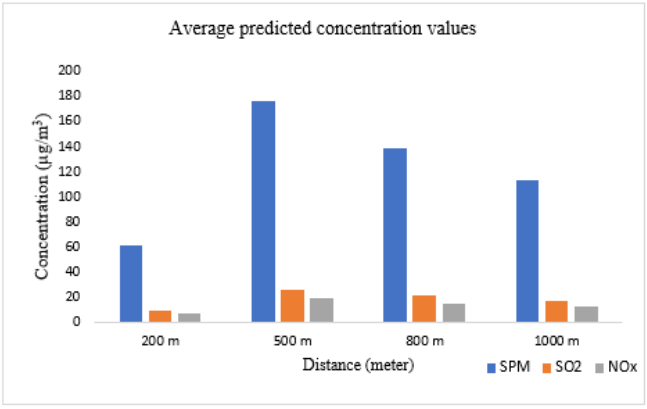

Fig. 4. Average predicted concentration values

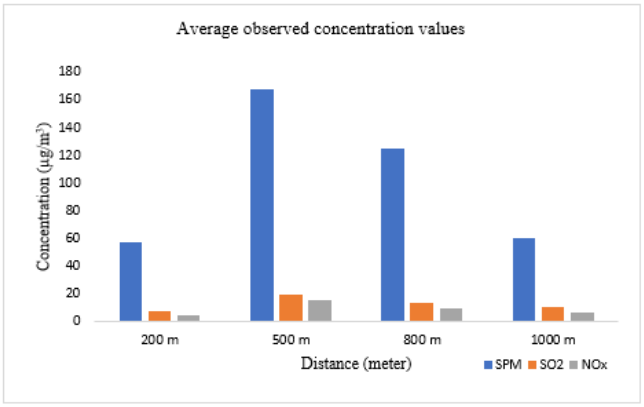

Fig. 5. Average observed concentration values

From the above table V and figures 4 and 5, it is found that the concentration of pollutants at discrete distances from the source is within the limits of NAAQS. Also, it can be seen that the concentration at 500m distance from the emission source has slightly elevated concentration levels but within the limits. The concentration of pollutants is gradually decreasing with respect to the distance from the emission source. It is due to the behaviour of plume due to atmospheric conditions. The input parameters like pollutant emission rates, wind speed, wind direction, terrain type, receptor height, receptor distance and stability class are given and then the SCREEN View software runs by using Gaussian air dispersion equation and gives the result in the form of concentration versus distance graph. The observed and predicted concentration value are nearer to each other.

C. *Model Evaluation*

TABLE VI. R^2 VALUE

Distance (m)	**R^2 value**		
	SPM	**SO_2**	**NO_x**
200	0.64	0.90	0.70
500	0.89	0.71	0.87
800	0.69	0.88	0.77
1000	0.93	0.82	0.84

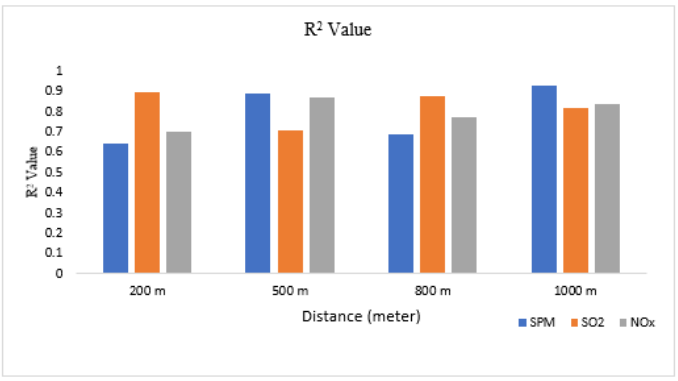

Fig. 6. R^2 Value

From the above table it is found that the R^2 value obtained by comparing the observed and predicted concentration value is greater than 0.6 ($R^2 > 0.6$), which means that the SCREEN View software shows good agreement between the observed and predicted concentration values and hence the model is reliable.

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IV. CONCLUSION

Air quality monitoring and stack emission monitoring was carried out to find out the emission rate and concentration of pollutants emitted from the stack. Ten stacks had been monitored in the foundry industry for SPM, SO_2, NO_2. Based on the predominant wind direction. Four station points to measure the ambient air quality had been selected along the downwind direction at discrete distances from the emission source (200m, 50m, 800m, 1000m). The concentration of pollutants emitted from the stack are within the permissible limits as per CPCB norms, it is due to the reason that the foundry industry follows the emission standards and having emission control devices like cyclone separator, cassette type filter, carbon filter, dust collector, bag filter. Based on the solar radiation and wind speed it was found that the stability of atmosphere in the study area is unstable. Thus, looping plume behaviour occurs.

Prediction of pollutant concentration at ground level along the centre line of the plume was done by SCREEN View software. The predicted result is obtained in the form of graph (Concentration vs Distance). A comparison is made between the observed and the predicted concentration values. Then, the evaluation of the model was done by finding the R^2 values of observed and predicted concentration values at each station points. All the R^2 values obtained is greater than 0.6 ($R^2 > 0.6$), which means that the SCREEN View model has good agreement between the observed and predicted concentration values. Hence it is concluded that, the SCREEN View model suits well for air dispersion modelling to find the ground level concentration and the model is reliable.

REFERENCES

[1] Adel A Abdel Rahman (2011),'On the Dispersion Models and Atmospheric Dispersion', International Journal of Global Warming, Vol.3, No.3.

[2] Anil J Sathe, Mutalik V G, et al. (2015),'Air Pollution Monitoring & Control at Foundry Clusters in Belgaum – A Case Study', International Journal of Civil and Environmental Research, Vol.7, No.5.

[3] Brusca S, Famoso F, et al. (2016),'Theoretical and Experimental Study of Gaussian Plume Model in Small Scale System', Journal of Energy Procedia, Vol.101, pp.58-65.

[4] Bureau of Indian Standard IS5182 (2006),'Methods for Measurement of Air Pollution', Part 23: Respirable Suspended Particulate Matter, Cyclonic Flow Technique.

[5] Bureau of Indian Standard IS11255 (2003),'Methods for Measurement of Emission from Stationary Sources', Part 1: Particulate Matter.

[6] Bureau of Indian Standard IS11255 (2009),'Methods for Measurement of Emission from Stationary Sources', Part 2: Sulphur Dioxide.

[7] Bureau of Indian Standard IS11255 (2012),'Methods for Measurement of Emission from Stationary Sources', Part 7: Oxides of Nitrogen.

[8] Guidelines for the Measurement of Ambient Air Pollutants, volume 1. (2011), Central Pollution Control Board (Ministry of Environmental & Forests, Govt. of India).

[9] Guidelines for the Measurement of Ambient Air Pollutants, volume 2. (2013), Central Pollution Control Board (Ministry of Environmental & Forests, Govt. of India).

[10] Health Effects of Air pollutants, World Health Organization, (2013).

[11] Krishnaraj.R, Dr.M.Sakthivel, et al. (2011),'A Journey towards Green Revolution – A Case Study of Foundry', International Journal of Science & Engineering Research, Vol.2, No.7.

[12] Mark D Gibson, Soumita Kundu, et al. (2013),'Dispersion Model Evaluation of PM2.5, NOx and SO2 from point and major line sources in Nova Scotia, Canada using AERMOD Gaussian Plume Air Dispersion Model', International Journal of Atmospheric research, Vol.4, pp.157-167.

[13] Mihaela Flori, Lucia Vilceanu (2017),'Prediction of Gaseous Pollutants Dispersion in Air', International Journal of Engineering, Vol.3.

[14] Palanivel M, Elayaraja T, et al. (2003),'Impact of Foundry Units on Coimbatore Environment'.

[15] Spiru Paraschiv, Gelu Coman, et al. (2019),'Simulation of Plume Dispersion Emitted from Industrial Sources based on Gaussian Model', AIP Conference Proceedings.

[16] www.cpcb.gov.in , Central Pollution Control Board website.

[17] https://app.cpcbccr.com/ccr , Live Air Quality Monitoring Station at Coimbatore.