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Air Pollution Dispersion Modeling for Diesel Generators at Jamia University Campus, New Delhi, India

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ABSTRACT

The study is conducted in order to assess the contribution of pollutants from the Diesel generators running in the Jamia Millia Islamia University Campus. In this work, ISCST3 air dispersion model was applied to simulate the air quality for 24 hourly average ground level concentrations of SOx, NOx, PM_{10} and 8 hourly average for CO at various receptor locations. Based on surveys and questionnaires, an inventory was formulated for different Gensets and their characteristics. The ISCST3 model is based on a steady-state Gaussian plume algorithm. It has been developed by USEPA for assessing air quality impact from point, area, and volume sources. Emission rates for different pollutants have been computed using empirical formulas for Gensets based on their capacity. Pollutant emitting potential has also been computed. The predicted values given by ISCST3 model are 11.33$\mu g/m^3$ for PM_{10}, 58.4 $\mu g/m3$ for SOx, 176.50 $\mu g/m^3$ for NOx, 57.02 $\mu g/m^3$ for CO. Both monitored and simulated values have been compared with NAAQS 2009. A possible solution for minimizing the pollutant load in the area via Diesel Gensets has been suggested in this research which will further help in managing the air quality scenario at the study area.

Keywords: *ISCST3; Air Quality; Modeling; Emission Rate.*

1.0 Introduction

With the advent of rapid urbanization and rising air pollution load, It has become quite essential to curb the air pollution exposure by precisely assessing the air quality [1-13]. The problem of Air pollution in Delhi has been in the spotlight for over a decade and it has now been recognized as a brainstorming issue for the whole nation [7,14]. Over the last two decades petrol and diesel consumption have grown by 400% and 300% respectively which has led to the rise of vehicular pollution as well as pollution due to other sources like DG sets, Industries, waste incinerators[8-16].

A typical diesel generator exhaust includes more than 40 toxic air contaminants including a variety of carcinogenic compounds like Benzene, Arsenic, Formaldehyde and Oxides of Nitrogen [9]. Emissions from diesel generators in the form of NOx, CO and Hydrocarbons chiefly contribute to the deteriorating air quality in the capital [10]. Many air quality models have been used throughout the world for air pollution dispersion that enables effective evaluation of the impacts of air pollution on urban air quality.

In 2003 Gooie et al. simulated the air pollution levels using ISCST3EM model caused by inner city traffic in Malaysia, and had compared the emissions with the available national and international standards, based on their analysis they were able to assess the potential health hazards caused by the air pollution so generated [11].

A comprehensive modeling study of PM_{10} in Treasure valley, Idaho(2011) was executed by Darko et al.

Their study utilized the services of ISCST3 model where the simulated values were found in agreement with measurements in both temporal and patterns and annual averages [12].

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2.0 Methodology

The main aim of this study is to model the air quality in Jamia University Campus, New Delhi, India by ISCST3 air quality modeling tool. The elevated levels of pollutant concentration due to Diesel based generators and their effects on the surrounding air quality have been studied in this research. This study has been executed in three stages, the first stage involves assimilation of generator data i.e. generator capacity, characteristics, location, fuel consumption, unit installation. Once the data was formulated then the next stage was executed where the pollutants emission rate for NOx, SOx, CO were computed so to be further utilized in ISCST3 model. In the next stage the pollutant potential of generator based on its capacity was determined and also the emission rate for each pollutant was computed. The final stage involves inputting all the required parameters for model run and comparison of simulated data with NAAQS.

2.1 Area of study

Jamia University being located on the south-east corner of Delhi is well connected to all key parts of the city. The university campus covers an area of almost 216 acres with a thick amount of green cover in the entire campus. The DMS latitude of the university is 28° 33' 41.9652" N and DMS longitude is 77° 16' 52.5288" E, laying in the UTM zone 43R the campus has an elevation of 215m. Based on number of source apportionment studies done it has been observed that diesel based generators contribute heavily in the deteriorating air quality of the campus. A total of 40 diesel generators of varying capacity have been installed at pertinent locations having a total capacity of 8650.5 KVA.

Fig 1: Genetorar location in the University Campus

2.2 Data collection of diesel generators

Following table 1 shows 10 out of 40 diesel generator sets fuel consumption rate @ 75% load (lt./hr) and actual place of installation with their Geographical locations.

There are around 40 diesel generators sets installed in different departments of the Jamia University varying from 15KVA to 1250 KVA. Fuel consumption data is based on diesel having specific Gravity of 0.85 and conforming to IS: 1460:2005. In this study we have considered generator operation time only 1 hr. in a day and 300 hrs in a year for the pollutants emission calculations. Total consumption of all Gensets is 1432.2 lt/hr(378.38 gal/hr).

Table 1: 10 Locations of Diesel Generators

Sr. No.	KVA	No.	Fuel consump-tion @ 75% load (lt/hr)*	Place of Installation	Co-ordinates x, y (m)	
					x	y
	-	-	-	Main gate of F/Engg.	0	0
1	125	01	20	Registrar Office	600	-70
2	140	01	22	Jamana Lal Bajaj House	636	-77
3	125	01	20	Middle School	460	266
4	250	01	42.6	Ansari Auditorium	518	-55
5	200	01	34.4	Main Building MCRC	620	-80
6	150	01	25	Studio Main Building MCRC	620	-80
7	63	01	11.5	Old Studio Building MCRC	620	-80
8	160	01	27.7	Bio-Science Building	620	-80
9	100	01	16.9	Department of Chemistry	620	-80
10	50	01	8.0	Examination Branch	650	-70

2.3 Air quality monitoring

Air Quality monitoring was conducted by ITL labs Pvt. Ltd. Delhi, with Respirable Dust Sampler (RDS) having model No. SLE RDS 103. It is manufactured by Spectro Lab Equipment Pvt. Ltd. Delhi. The filter paper used for this monitoring was "Glass micro fibre filter" and the size was 20.3X25.4 cm. Sampler was installed at the Gate No. 1 of Faculty of Engg. & Technology (Jamia University).

Sampling was done for the pollutants CO, NOx, SOx & PM_{10} on hourly basis, from 1000 hrs. to 1800 hrs.[17]. Monitored value from Respirable Dust Sampler (RDS) are given in table 2.

Table 2: 8 Hrs Monitored Value From Rds

S No	Parameters	Unit	Permissible Limit as per NAAQ 2009 Standard	Monitored Value
1	CO	µg/	2000 (8 hr.)	1140
2	SO_x	µg/	80	18.7
3	NO_x	µg/	80	57.8
4	PM_{10}	µg/	100	392

3.0 Air Quality Modeling

Ambient air concentration levels of PM_{10}, SOx and NOx have been predicted in winter season using the Industrial Source Complex Short Term (ISCST3) model. The ISCST3 model is based on a steady-state Gaussian plume algorithm, and is applicable for estimating ambient impacts from point, area, and volume sources out to a distance of about 50 kilometers.

3.1 Modeling Requisite

3.1.1 Characteristics of different gensets

Installed generators characteristics have been shown under which includes, stack height, exit temperature of flue gas, exit velocity and exhaust diameter of generator. Out of 40 generators only 10 have been represented in the table.

Table 3: Genset Data Required For Model Run [3-4]

Genset Sr. No.	KVA	Stack Height (HS), m	Exit Temp. (Ts) (K)	Exit Velocity (Vs), m/s	Exhaust Dia (Ds), mm
1	125	22	600	6	115
2	140	22	600	8	165
3	125	22	600	6	115
4	250	25	700	10	200
5	200	25	650	10	180
6	150	22	600	8	165
7	63	20	550	5	90
8	160	22	650	8	165
9	100	20	550	6	115
10	50	20	550	5	90

3.1.2 Fuel consumption and emission rates for different Gensets

The Emission rate calculation has been shown below:

Emission rate for SOx in g/s

$$= \frac{\text{Fuel consumption rate x Density of diesel x1000grams}}{1800}$$

Emission rate for NOx in g/s

$$= \frac{\text{3.85 x Dieselgenerator capacity in Hp}}{3600}$$

Emission rate for PM10 in g/s

$$= \frac{\text{0.24 x Dieselgenerator capacity in Hp}}{3600}$$

Emission rate for CO in g/s

$$= \frac{\text{0.045 x Dieselgenerator capacity in Hp}}{3600} \quad [1\text{-}5]$$

Table 4: Fuel Consumption and Emission Rates of 10 Gensets [1-2]

Sr No.	Rating (hp)	Fuel intake (l/hr)	Sox Emission Rate Qs (g/sec)	NOx Emission Rate Qs (g/sec)	PM_{10} Emission Rate Qs (g/sec)	CO Emission Rate Qs (g/sec)
1	142.38	20	0.047	0.152	0.009	0.045
2	159.46	22	0.052	0.171	0.011	0.051
3	142.38	20	0.047	0.152	0.009	0.045
4	284.75	42.6	0.101	0.289	0.015	0.078
5	227.80	34.4	0.081	0.231	0.015	0.062
6	170.85	25	0.059	0.183	0.011	0.055
7	71.76	11.5	0.027	0.079	0.008	0.044
8	182.24	27.7	0.065	0.185	0.010	0.050
9	113.90	16.9	0.040	0.122	0.008	0.036
10	56.95	8	0.019	0.063	0.006	0.035

4.0 Model Run

Data required for model run for predicting pollutant concentration are:

(i) Source data: physical dimensions (stack location, stack height, stack top inner diameter), as well as exit velocity and temperature of gas and pollutant emission rate,

(ii) Hourly meteorological data for the simulation period: wind speed, wind direction, ambient temperature, stability class and mixing height

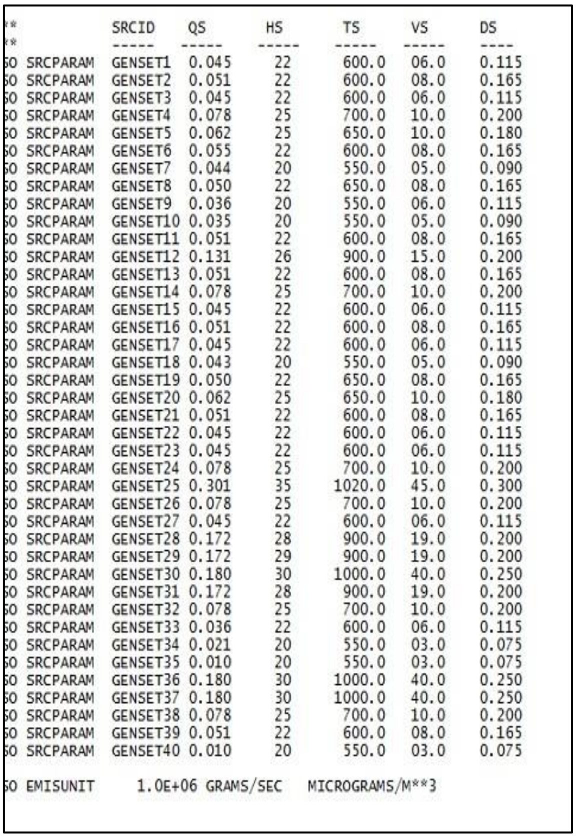
(ii) Receptor data: receptor coordinates and height of receptor

The Input parameters for CO required by ISCST3 model after inputting all the required parameters has been shown in figure 2.

5.0 Result

The ground level pollutants concentrations of PM_{10}, SOx, NOx & CO for this study were predicted through ISCST3 model. The maximum values of average predicted PM_{10}, SOx, NOx and CO concentrations have been shown in table 5.

Fig 2: ISCST3 Model Run for CO



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**                SRCID     QS       HS      TS      VS      DS
**                -----    -----    -----   -----   -----   ----
SO SRCPARAM  GENSET1  0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET2  0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET3  0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET4  0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET5  0.062    25     650.0   10.0    0.180
SO SRCPARAM  GENSET6  0.055    22     600.0   08.0    0.165
SO SRCPARAM  GENSET7  0.044    20     550.0   05.0    0.090
SO SRCPARAM  GENSET8  0.050    22     650.0   08.0    0.165
SO SRCPARAM  GENSET9  0.036    20     550.0   06.0    0.115
SO SRCPARAM  GENSET10 0.035    20     550.0   05.0    0.090
SO SRCPARAM  GENSET11 0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET12 0.131    26     900.0   15.0    0.200
SO SRCPARAM  GENSET13 0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET14 0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET15 0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET16 0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET17 0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET18 0.043    20     550.0   05.0    0.090
SO SRCPARAM  GENSET19 0.050    22     650.0   08.0    0.165
SO SRCPARAM  GENSET20 0.062    25     650.0   10.0    0.180
SO SRCPARAM  GENSET21 0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET22 0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET23 0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET24 0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET25 0.301    35    1020.0   45.0    0.300
SO SRCPARAM  GENSET26 0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET27 0.045    22     600.0   06.0    0.115
SO SRCPARAM  GENSET28 0.172    28     900.0   19.0    0.200
SO SRCPARAM  GENSET29 0.172    29     900.0   19.0    0.200
SO SRCPARAM  GENSET30 0.180    30    1000.0   40.0    0.250
SO SRCPARAM  GENSET31 0.172    28     900.0   19.0    0.200
SO SRCPARAM  GENSET32 0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET33 0.036    22     600.0   06.0    0.115
SO SRCPARAM  GENSET34 0.021    20     550.0   03.0    0.075
SO SRCPARAM  GENSET35 0.010    20     550.0   03.0    0.075
SO SRCPARAM  GENSET36 0.180    30    1000.0   40.0    0.250
SO SRCPARAM  GENSET37 0.180    30    1000.0   40.0    0.250
SO SRCPARAM  GENSET38 0.078    25     700.0   10.0    0.200
SO SRCPARAM  GENSET39 0.051    22     600.0   08.0    0.165
SO SRCPARAM  GENSET40 0.010    20     550.0   03.0    0.075

SO EMISUNIT     1.0E+06 GRAMS/SEC   MICROGRAMS/M**3
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The maximum value for PM_{10} concentration has been observed 11.33 μg/m^3, at the receptor location (800.00, 0.00, and 0.00). In fact, the predicted PM_{10} value when compared with the standard value of 24 hourly PM_{10} concentration prescribed by the CPCB was found to be much lower. The predicted ground level SOx concentration of 58.37 μg/m^3 was observed which was found to be within the CPCB standard/limits of 80 μg/m^3.

Table 5: Predicted and Monitored Values in Comparison with NAAQS

Sr no.	Air quality parameters	Time weighted average	Max predicted values, (μg/m^3)	Monitored values (μg/m^3)	National ambient air quality standard, (μg/m^3)
1	PM_{10}	24 hr	11.33	392	100
2	SOx	24 hr	58.40	18.7	80
3	NOx	24 hr	176.50	57.8	80
4	CO	8 hr	57.02	1140	2000

Finally the predicted maximum value of 176.49 μg/m^3 was simulated for NOx and the value exceeded the CPCB standard/limits of 80 μg/m^3 for the residential area. The comparison between observed and simulated data has been shown in figure 3.

Fig 3: Comparison of Predicted and Observed Data

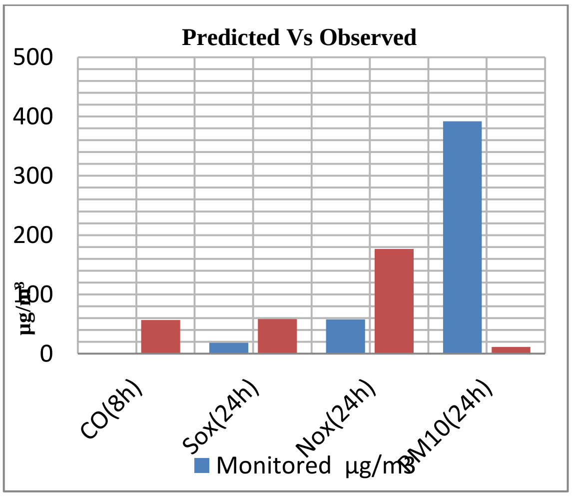

Table 6: Comparison between 40 Gensets Conc. & Recommended 4 Gensets Concentration

S. No.	Air quality parameters	Time weighted average	Conc. from 40 Gensets (8650kva), μg/m3	Conc. from 4 Genset (2500 kvaX4), μg/m^3
1	PM_{10}	24 hr	11.33	4.41
2	SOx	24 hr3	58.4	26.47
3	NOx	24 hr	176.5	166.56
4	CO	8 hr	57.02	16.2

Fig 4: 40 Gensets vs 4 Gensets Concentration

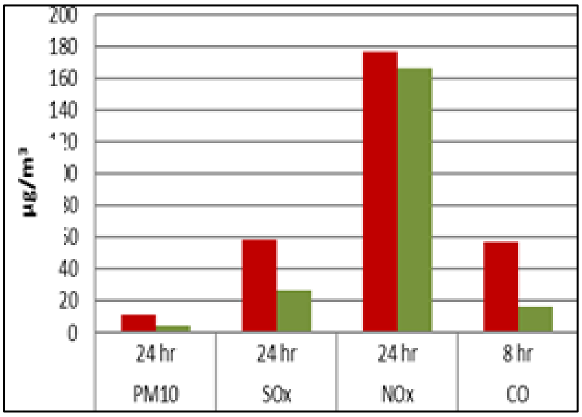

Fig 4: 40 Gensets vs 4 Gensets Concentration

Concentration from 40 Gensets(8650kva), μg/m3	11.33	58.4	176.5	57.02
Concentration from 4 Genset(2500 kvaX4), μg/m3	4.41	26.47	166.56	16.2

6.0 Conclusions

ISCST3 and local meteorological data were used to predict the concentration of major air pollutants in the campus area. Our findings indicate that after the implementation of the proposed project, concentrations of air pollutant are found to be well below the permissible CPCB Standards for ambient air quality.

However, the PM concentration is elevated due to the Construction, traffic and diesel generators implementing proper Environmental Management Plan along with mitigation measures like Water sprinklers, and trees planting, around the industrial area can minimize the pollution and protect the environment from the adverse effects.

If 4 Gensets having capacity 2500 kVA installed, instead of 40 Gensets of 8650 kVA capacity, the pollutants concentration will be reduced nearly half of their previous concentration value for PM_{10}, SOx & CO. The findings will assist in improving the air quality index and scenario around the campus, their prior implementation will decrease load on generators running in and around the campus which will further improve the surrounding air quality.

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