

**EMISSION INVENTORY OF AIR POLLUTANTS FROM DIESEL
GENERATOR USED AT SELECTED LOCATIONS IN JAIPUR CITY, INDIA**Gourav Suthar¹, R. K. Malik², Nivedita Kaul³¹Department of Civil Engineering, Amity University Gurugram, India,²Department of Civil Engineering, Amity University Gurugram, India,³Department of Civil Engineering, Malaviya National Institute of Technology, Jaipur, India,

Abstract— *The use of diesel generator (DG) sets for power backup at various places like malls, shopping centres, wedding gardens, offices buildings etc. increases the air pollution levels in the cities and causes severe health and environmental problems. A study of emission inventory for the air pollutants released from the diesel generators used at malls, shopping centres and wedding gardens in Jaipur city, India has been carried out to estimate concentration of air pollutants viz: oxides of nitrogen (NO_x), oxides of sulphur (SO_x), particulate matter (PM₁₀), hydrocarbon (HC) and carbon monoxide (CO) by using questionnaire survey of the users comprising of managers and DG operators. 16 wedding gardens, 6 malls and 2 shopping centres located within the city were identified for calculation of data for the period between May 2018 to July 2018. It has been observed that in the wedding gardens 62, 125 and 250 KVAs of DG sets are used, whereas, malls and shopping centres used 8 types DG sets ranges from 62 to 1650 KVA. In wedding gardens, the estimated emission rate of air pollutants from 250 KVA DG set (running with the average of 3 hours per day) emit 0.183 kg/day of PM₁₀, 3.08 kg/day of NO_x and 1.50 kg/day of CO. 62 KVA DG sets produces 0.072 kg/day of PM₁₀, 1.296 kg/day of NO_x and 0.77 kg/day of CO.*

Keywords: *Emission Inventory, Pollutants, Particulate Matter, Environment, Concentration*

I. INTRODUCTION

In the last two decades the global warming has increased which has created the various environmental problems. The diesel generators are contributing to the environmental problems which are the sources for the distributed generation of electricity [1]. These can also be used at peak demand of electricity and for backup for the electricity distribution systems [2]. A study by Environmental Protection Agency (EPA) reported that the global warming is caused due to the change in concentration of air constituents which are measure by accumulating a database for discharge of air pollutants into the atmosphere called as emission inventory [3]. An emission inventory generally comprises of the total greenhouse gases in a specific geographical area within a definite time span [4]. The International Energy Agency (IEA) estimates that the discharges of CO₂ will increase by 92 percent from the year 1990 to 2020 and it has been projected that 8.6 billion metric tons of CO₂ will be emitted into the atmosphere from the year 2020 to 2035 [5,6]. During the last two decades in India, diesel and petrol consumption has risen by 300 percent and 400 percent, respectively due the rise of transportation as well as by using DG sets, waste incinerators and industries [7]. Emissions of pollutants from the DG sets give rise to deterioration of air quality and have negative effects on human health in the surrounding environment [8]. A specific DG exhaust contains more than 40 air pollutants which include SO_x, NO_x, CO₂, CO, HC etc. besides various containing carcinogenic compounds such as arsenic, benzene and Formaldehyde. Emissions from DG in the form of NO_x, SO_x, CO₂, PM₁₀, CO and HC are the primarily pollutants influencing the poor air quality in a particular region [9]. However, the operation of DG sets increases the unsafe and damaging factors (exhaust gases, vibration, noise) which break the ecological balance of an area. The gases from diesel engines constitute of solid particles and their presence in the air cause serious illness as well as oncological violations [10]. The gases that emit from DG sets are very harmful for living beings which are also responsible for the ozone layer degradation and formation of carcinogenic substances leading to premature deaths [11]. The aim of this study is to estimate the concentration of air pollutants from the DG sets use at wedding gardens, malls and shopping centres in Jaipur City, India.

II. METHODOLOGY**A. Selection of City**

Jaipur city located at latitude 26° 55' 19.4520" N and longitude 75° 46' 43.9860" E has a population of 3.1 million [12]. The location of Jaipur city is shown in Fig. 1. With the increase in urbanization the demand of electricity has increased but still not meeting the energy demand. So, people are using diesel generator sets for their electricity power backups. DG sets generates various types of air pollutants which are further contribute to the poor air quality of an ambient environment which has been measure as Air Quality Index (AQI). As per Central Pollution Control Board (CPCB) (2017), the AQI increased to 247 in 2017 [13]. The AQI at Police Commissionerate air pollution station in Jaipur city reported 220 on 13 November 2018 [14].

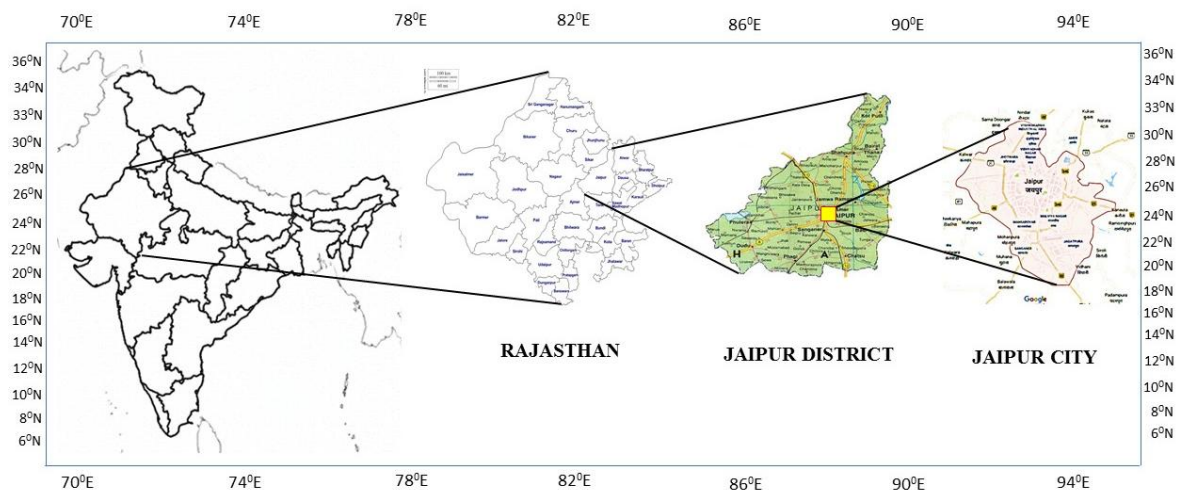


Fig. 1 Location of Jaipur city

B. Site Selection

1) *DG Sets at Wedding Gardens:* The selection of sites has been made on the basis on the areas, capacity and DG sets usage. The data has been collected by conducting a questionnaire survey at malls, shopping centres and wedding gardens in the city to identify the factors such as amount of fuel consumed by a DG sets, operational time, maintenance duration, age, vendors etc. Managers and DG operators has been identified as respondents. 16 wedding gardens, 6 malls and 2 shopping centres were selected for the study which used 8 types of DG sets ranges from 62 to 1650 KVA. The locations of the malls and shopping centres are shown in Fig. 2.

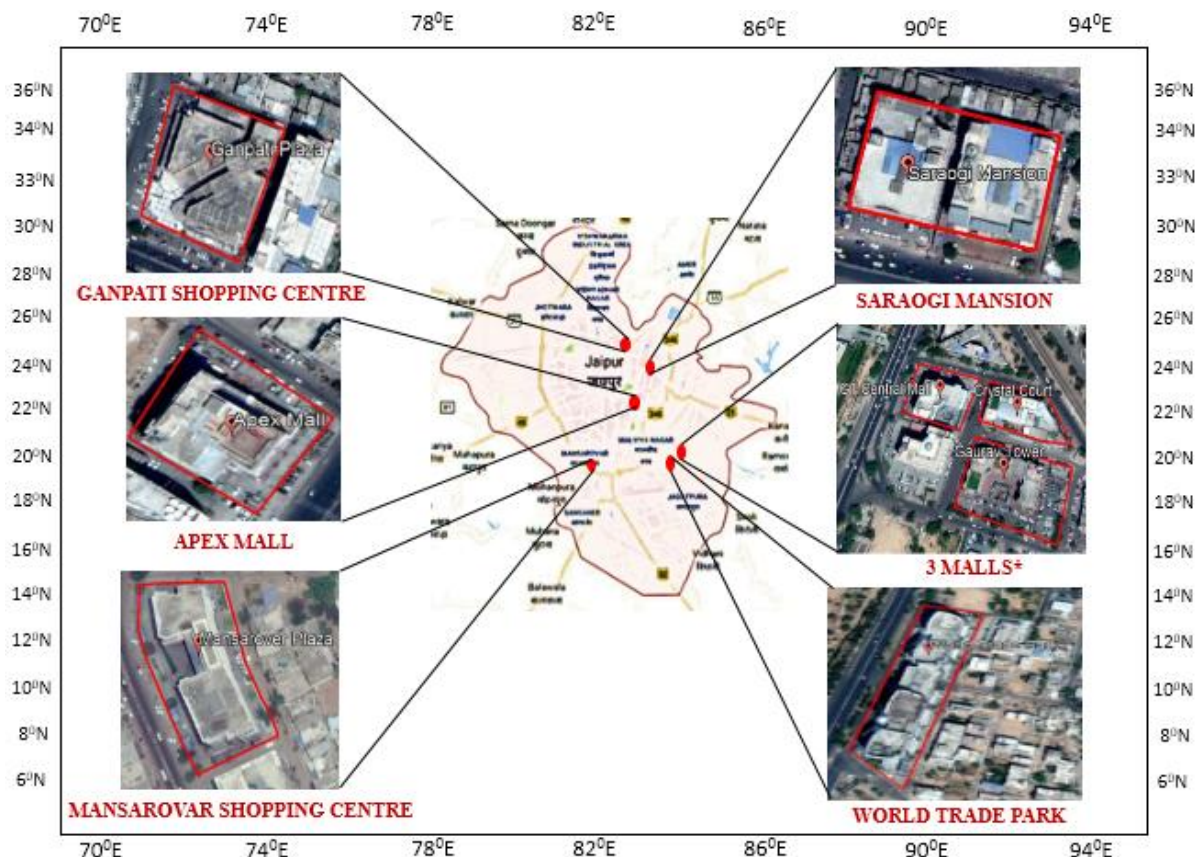


Fig. 2 Location of malls and shopping centres in Jaipur city

C. Estimation of Concentration of Air Pollutants in Jaipur City

For estimating the rates for air pollutants i.e. NO_x and PM_{10} by the method as described by Masood et al. has been used [15]. Whereas, the air pollutants which were CO , SO_x and HC have been estimated by the method described by Rukmini et al. [16]. The conversions of KVA to Kilowatt (KW) and KW to Horsepower (HP) have been made as reported by Diesel Service and Supply Industry (DSSI) [17]. The power factor is considered as 0.8 for DG sets [18]. The formulas based on the above references [15-18] are described as:

i. Emission rate of NO_x

$$\text{NO}_x \text{ (gm/s)} = [3.85 \times \text{DG set capacity in HP}] / 3600 \quad (1)$$

ii. Emission rate of PM₁₀

$$\text{PM}_{10} \text{ (gm/s)} = [0.24 \times \text{DG set capacity in HP}] / 3600 \quad (2)$$

iii. Emission rate of carbon monoxide (CO)

$$\text{CO} = 15 \times 10^{-3} \times P^{0.68} \times N \quad (3)$$

Where, P = Engine power in (KW) x engine load (85 %); N = number of DG sets

iv. Emission rate of hydrocarbons (HC)

$$\text{HC} = 4.86 \times 10^{-3} \times P^{0.69} \times N$$

(4)

v. Emission rate of Sox

$$\text{SO}_x = 2.31 \times 10^{-3} \times P \times N \quad (5)$$

III. Results and Discussion

A. Emission Rate of Air Pollutants

The capacity of DG sets (range from 60 to 1650 KVA) which are installed at different locations i.e. wedding gardens, malls and shopping centres are given in Table 1.

TABLE I
CAPACITY OF GENERATOR IN KVA, KW, HP

Generator's Capacity (KVA)	Generator's Capacity (KW)	Generator's Capacity (HP)
1650	1320	1796.436
500	400	536.193
250	200	268.096
160	128	171.581
150	120	160.857
125	100	134.048
100	80	107.238
62	50.4	67.560

The emission rate of the air pollutants from the DG sets depends upon the amount of fuel it consumes, its age, operational time, maintenance etc. Table 2 shows the estimated emission rate of NO_x, SO_x, CO, HC and PM₁₀. DG sets with capacity of 1650 KVA generator shows the huge amount of air pollutants released because it consumes 300 litres per hour (lt/hr) of diesel which releases 0.119 gm/s (gram/second) of PM₁₀ and very high amount of NO_x which was about 1.949 gm/s. The DG sets with capacity 125 KVA (used for on an average 3 hours in day) is used at majority of the wedding gardens. By consuming diesel about 20 lt/hr it released 0.008 gm/s of PM₁₀, 0.143 gm/s of NO_x, 0.064 gm/s of SO_x, 0.087 gm/s of CO and 0.029 gm/s of HC. The generator with 62 KVA capacity which is used at few malls and shopping centres but mainly used at wedding gardens. 62 KVA generator consumed on an average 10 lt/hr and emits concentration of PM₁₀, NO_x, SO_x, and CO which are estimated as 0.004, 0.072, 0.032, and 0.054 gm/s, respectively.

TABLE II
EMISSION RATE OF AIR POLLUTANTS

Capacity of DG (KVA)	Average fuel Consumption (lt/hrs)*	PM ₁₀ (gm/s)	NO _x (gm/s)	SO _x (gm/s)	CO (gm/s)	HC (gm/s)
1650	300	0.119	1.949	0.847	0.504	0.171
500	70	0.035	0.572	0.256	0.224	0.075
250	35	0.017	0.286	0.128	0.139	0.046
160	30	0.011	0.183	0.082	0.103	0.034
150	25	0.010	0.171	0.077	0.098	0.032
125	20	0.008	0.143	0.064	0.087	0.029
100	15	0.007	0.114	0.051	0.075	0.024
62	10	0.004	0.072	0.032	0.054	0.018

*Average fuel consumption of DG used at 16 wedding gardens, 6 malls and 2 shopping centres

1) *Emission Rate of Air Pollutants from DG Sets at Wedding Gardens:* Three types of generators are used at wedding gardens which are 60, 125 and 250 KVAs which produce different emission rates of pollutants. Their emission rates are estimated by the operational time and diesel quantity they consume. 250 KVA generator is often used in the wedding gardens but a few wedding gardens in Jaipur city use this capacity of generator which are operational for 3 hr/ day and emit PM₁₀, NO_x, SO_x, CO and HC are 0.183, 3.08, 1.38, 1.50 and 0.49 kg/day, respectively. However, the emission rates of pollutants were less observed in 62 KVA generator sets which operated for 5 hr/day and released 0.77 kg/day of CO and 1.296 kg/day of NO_x in the atmosphere, respectively.

TABLE III
 EMISSION RATE OF AIR POLLUTANTS FROM DG SETS AT WEDDING GARDENS

DG set (KVA)	Average* Operational time (hr/day)	Concentration of air pollutants by a DG				
		PM ₁₀ (kg/day)	NO _x (kg/day)	SO _x (kg/day)	CO (kg/day)	HC (kg/day)
250	3	0.183	3.08	1.38	1.50	0.49
125	4	0.115	2.05	0.92	1.25	0.41
62	5	0.072	1.296	0.57	0.77	0.324

* Average operational time DG used at 16 locations of wedding gardens

2) *Emission Rate of Air Pollutants from DG Sets at Malls and Shopping Centres:* The Gaurav Tower mall used 6 types of generators of capacities 62, 100, 150, 160, 250 and 500 KVAs and emitting huge amounts of NOX SOX, CO. 500 KVA DG produce NOX which has been observed to be 6.177 kg/day, 2.764 kg/day SOX and 2.419 kg/day of CO. It can be observed from Table 4 that the World Trade Park having huge capacity of generator (1650 KVA) and generate emission rates of 7.016 kg/day of NOX, 3.049 kg/day of SOX, 0.428 kg/day of PM10 and 0.615 kg/day of HC. If the current trend of using DG continues then it will degrade the environmental quality. Crystal Court, Mansarover Shopping centre, Ganpati Shopping centre and Saraogi Mansion uses only one type of DG set (250 KVA) and all them are operational for 1 hour/day.

TABLE IV
 EMISSION RATE OF AIR POLLUTANTS FROM DG SETS AT MALLS AND SHOPPING CENTRES

Malls or Shopping centre	Average Operational Time (hr/day)	Capacity (KVA)	Concentration of air pollutants				
			PM10 (kg/day)	NO _x (kg/day)	SO _x (kg/day)	CO (kg/day)	HC (kg/day)
Gaurav Tower	3	62	0.043	0.777	0.345	0.583	0.194
		100	0.075	1.231	0.550	0.810	0.259
		150	0.108	1.846	0.831	1.085	0.313
		160	0.118	1.976	0.885	1.112	0.345
		250	0.183	3.088	1.382	1.501	0.367
		500	0.378	6.177	2.764	2.419	0.496
GT Central Mall	2	500	0.252	4.118	1.843	1.612	0.331
World Trade Park	1	1650	0.428	7.016	3.049	1.814	0.615
Crystal Court	1	250	0.061	1.029	1.382	0.500	0.165
Saraogi Mansion	1	250	0.061	1.029	1.382	0.500	0.165
Ganpati Shopping centre	1	250	0.061	1.029	1.382	0.500	0.165
Mansarover Shopping centre	1	250	0.061	1.029	1.382	0.500	0.165
Apex Mall	3	62	0.043	0.777	0.345	0.583	0.194
		100	0.075	1.231	0.550	0.810	0.259
		250	0.183	2.700	1.382	1.501	0.367

IV. CONCLUSIONS

The study is carried out for the emission inventory of diesel generators used between the months of May 2018 and July 2018 at the various locations like wedding gardens, malls and shopping centres in Jaipur City, India. The emission rates of PM₁₀, NO_x, SO_x, CO and HC are estimated for 8 types of DG sets ranges from 62 to 1650 KVAs. The estimated emission rates of NO_x, SO_x and CO from all generators are very high. The generators with capacity of 62 KVA use at wedding gardens emitted 0.072 kg/day of PM₁₀ and 125 KVA generator emits 0.115 kg/day of PM₁₀, respectively. 250 KVA capacity of DG sets use at shopping centres emitted PM₁₀ which was observed to be 0.061 kg/day, 1.029 kg/day of NO_x, 1.382 of SO_x, 0.583 kg/day of CO and 0.165 kg/day of HC. Among all DG sets, the highest amount of air pollutants emission is estimated from the use of 1650 KVA capacity of generator which consumes diesel quantity of

about 300 lt/hr and shows the emission rate was observed for NO_x which is 7.016 kg/day, 0.428 kg/day of PM₁₀, 3.049 kg/day of SO_x, 1.814 kg/day of CO and 0.615 kg/day of HC in the atmosphere.

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