

Modeling CO, CO₂ and NO_x Evolution from Small and Medium Size Electric Gensets

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Abstract The Carbon monoxide, Carbon dioxide and Nitrogen oxides emission data from 100 small and medium generator sets with capacity ranging from 10 to 20 kVA are obtained from portable combustion gas analyzer using KAN90PLUS model. The resolutions for measurement for the gasses are 1 ppm, 0.1ppm and 1ppm respectively. The emission of the gasses together with the temperature of the exhaust and generator set capacities are studied. The models used for the study are calibrated using some polynomial interpolation methods and the results obtained compare with the emission benchmark value of the environmental management (Air Quality Standard) of 2007. It is found that the sets emits excessive carbon monoxide far above the standard value 175mg/nm². The nitrogen oxide produces high temperature in the combustion system. Moreover, using asymptotic analysis, for large generator capacities, nitrogen oxides emission tends to be decreasing compared to the small and medium generators. The nitrogen oxides emission tends to converge to 20.189T, T is the temperature of the exhaust in Kelvin. Polynomial interpolation method used for prediction of CO, CO₂ and nitrogen oxides (NO_x) with respect to generator capacity and then simulation for the emission of the gasses at various scenarios carried. We Proposed emission and spread functions and simulate the functions to obtain the random emission and random spread of the gases into the environment from the available emission data for the gases. From our finding large quantity of CO, CO₂ & NO_x, are being emitted by the generators sets and this will have serious effect on the air quality in the remote environment where small and medium size generator sets are being used for generating electricity. The agricultural productive of the community will also be affected because of possible acid rain in that environment couple with allergic and respiratory diseases because of emission of the poisonous gases to the remote environment. As a policy, only generator sets with low emission should be allowed into the developing countries.

Keywords: modeling, emissions, carbon monoxide, carbon dioxide, nitrogen oxides, electric generators

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1. Introduction

The use of fossil fuels in stationary and mobile engines is the single most important contributor to anthropogenic greenhouse gases. For instance, it is estimated that transport alone is responsible up to a quarter of the global greenhouse gases [1] whereas the industry and other anthropogenic activities are responsible for the remaining three quarter global emission of the greenhouse gases. It is now widely accepted that the accumulation of the greenhouse gases that result in climate change is negatively influencing public health and welfare [2,3]. In the Tanzania context, energy sector is second most important sector, after agriculture (94.98%), as it emits 4.41% of total CO₂ emissions [4]. In Nigeria combustion of fossil oil is the major contributor of CO₂ and other greenhouse gases into the Nigeria airspace [5].

The main source of CO₂ emissions from the energy sector is from thermal power plants that utilize fossil fuels

to generate electricity. Isolated off-grid areas are the major user of fossil fuel for electricity generation, and hence the major contributor of fossil CO₂, and more emissions are produced during power cuts that forces all standby generator sets to be engaged. Thus for the purpose of mitigating these emissions, it is important to understand their evolution characteristics and the influencing features.

The temperature of the earth is found to be increasing because of the greenhouse gases. The combustion of fuel in the generator sets produces Carbon Monoxide (CO), Carbon Dioxide (CO₂), Nitrogen Oxides (NO, NO_x) and Sulphur dioxides (SO₂). The incomplete combustion of gasoline supplies much of the volatile organic compound which, in turn, combines with sunlight to produce unhealthy levels of ozone [5]. Under high temperature nitrogen will combine with oxygen to form a class of nitrogen oxides. Nitrogen oxides and sulphur dioxide with water give rise to acid rain which is dangerous to human health and biodiversity [6].

Modeling toxic fumes in form of greenhouse gases, Volatile Organic Compounds (VOCs) and Respirable

Suspended Particulates (RSPs) have been subject of many researches in the recent times [7,8]. The reason d'état are that pollutants have been established to have negative effect on human health, ecosystem imbalance and global warming. One of such models is the EMFAC_HK model developed for estimating vehicular tailpipe emission of CO, CO₂, NO_x, VOCs and RSPs emission from petrol vehicles (EPA).

The model for studying aerodynamic behavior of particulates that diffused into the airways in the human lower respiratory track and the attendant medical implication has been considered [6]. Ezaina and Saheed modeled the global emission of pollutants emanating from flaring of natural gases from industries and released of greenhouse gases into the environment. Krzywaski and Norwalk [9] calculated CO₂, CO, SO₂, O₂ and NO emission from coal combustion in air and oxygen enriched circulating fluidized bed boiler.

The CO₂ emission auditing in the Nigeria airspace have been done using greenhouse training equation, artificial neural network model, polynomial fitting method by Oyelami and Buba [5]. The researchers predicted CO₂ emission and CO₂ emission per capita of Nigeria from 2013 to 2030.

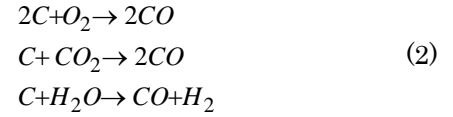
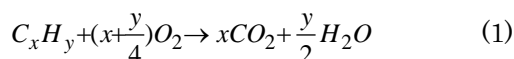
This paper aims at developing models that describes the evolution characteristics of carbon monoxide (CO), carbon dioxide (CO₂) and nitrogen oxides (NO_x) emitted from small and medium generator sets. In the energy sector under consideration, the emissions of CO, CO₂, and NO_x generated during fossil fuels combustion are of paramount importance when designing generator sets that would conform to standard air quality requirements. Therefore, the evolution of the individual emission being governed by specific phenomena needs to be understood. The best mitigation plan must, therefore, take into consideration of their evolution characteristics.

We intend to use polynomial interpolation method to obtain prediction of CO, CO₂, nitrogen oxides (NO_x) and then carried simulation for the emission of the gasses at various scenarios. In order to understand the random emission of pollutant gases into atmosphere, we proposed emission and spread functions. We will simulate the emission and spread functions to obtain information on the emission and spread of the gases into the environment using the available emission data.

2. Evolution Characteristics and emission of Carbon Dioxide, Carbon Monoxide and Nitrogen Oxides

2.1. Carbon Dioxide Emissions

As described in equation (1) all combustion processes result in the production of carbon dioxide and water. Thus the carbonaceous materials are oxidized with oxygen to produce carbon dioxide and water and thereby releasing heat.



2.2. Carbon Monoxide Emissions

In the event the combustion is not complete, the carbon monoxide becomes more evident in the generator engine's exhaust. Thus poorly maintained generator sets and those which are not well-tuned they usually exhibit excessive carbon monoxide since the carbon does not get sufficient oxygen for producing CO₂ (equation 2). The production of CO is at the carbon surface where the carbon can either be attacked by oxygen (O₂), carbon monoxide (CO₂) or water (H₂O). Carbon monoxide is not a greenhouse gas. However it is poisonous when inhaled.

2.3. Nitrogen Oxides Emissions

The existing stringent environmental regulations on the greenhouse effect of the oxides of nitrogen, commonly known as NO_x, require understanding their formation mechanisms for designing effective interventions. A detailed count of NO_x formation mechanism is detailed in Gardiner Jr. [10] and Glassman [11] where the authors gave comprehensive reviews on nitrogen oxide (NO) which is known to be formed in a variety of ways: (1) "Thermal NO" is primarily a consequence of high flame temperatures; (2) "Prompt NO" is generated in fuel-rich parts of flames; (3) the "N₂O mechanism" is common in high-pressure flames; (4) "Fuel nitrogen NO" results from converting the nitrogen constituents of the fuel (petroleum, coal and biomass) into NO; and (5) the "NNH mechanism" is pronounced in flame fronts with high atom concentrations appear. Thus, with the exceptions of "fuel nitrogen" mechanism, all the remaining mechanisms convert atmospheric (from combustion air) nitrogen into NO.

The principal reactions in the thermal NO formations are:



Due to the high activation (320 kJ/mol) of equation (3), the thermal mechanism is predominant in high temperature combustion zones.

In Figure 1 we consider, the emission of CO, CO₂, NO & NO_x from various sources; x is the capacity of the generator sets and n_1, n_2, \dots, n_N are the number of the generator sets from the i^{th} community, $i = 1, 2, \dots, N$. Each block of building in the Figure 1 represents a community with pool of generators sets emitting gases into the neighborhood atmosphere. We intend to develop models to determine the emission and spread of CO, CO₂, NO & NO_x to the environment in a network fashion.

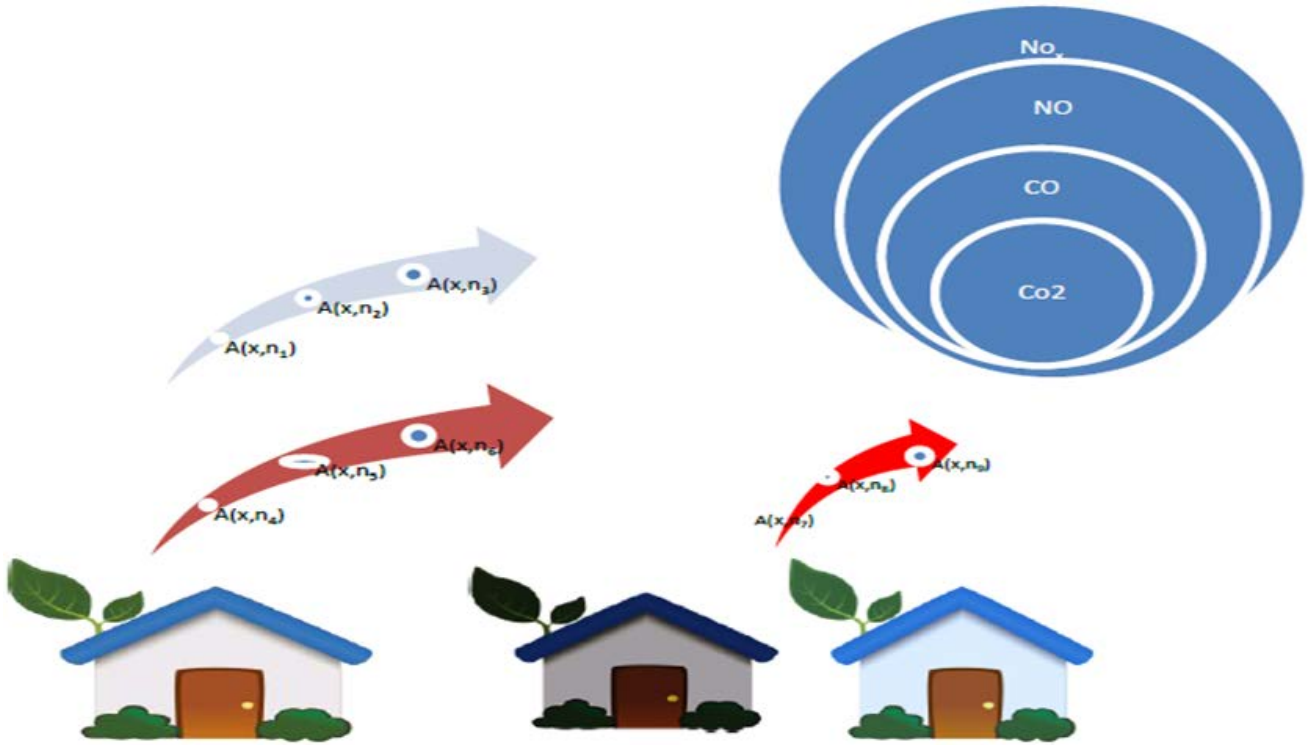


Figure 1. Pollution of the environment from pool sources

3. Methods and Materials

This paper bases on in environmental auditing of a combustion system in which one of the requirements is to assess environmental performance of existing combustion systems like generator sets. A databank of emissions from 100 previously assessed generator sets was utilized for the modeling purpose. As detailed in Table 1, the generator sets were 100 different small to medium size kVA generator sets with capacities ranging from 10 to 20 kVA. The portable combustion gas analyzed model KANE900 PLUS was utilized for emissions assessment. Its resolution for measurement of CO, CO₂ and NO is 1 ppm, 0.1 ppm, and 1 ppm.

Table 1. Generator set quantities and capacity (kVA)

SNO.	CAPACITY, kVA	GENERATORS QUANTITY
1	10.00	3
2	12.00	4
3	13.00	9
4	13.50	3
5	14.00	4
6	15.00	3
7	16.00	31
8	16.50	13
9	17.00	4
10	20.00	26
TOTAL		100

3.1. Emission and Spread of Gases Functions

The distribution of the gases into the atmosphere $D(x)$ can provide important information about emission of gases. We define the emission distribution function as

$$E(x) = \frac{1}{\sqrt{2\pi}\sigma} \int_0^x f(v) e^{-\frac{1}{2}(\frac{v-\bar{x}}{\sigma})^2} dv \quad (6)$$

Where $f(v)$ is the estimate of the emission of the gases from the emission data from the generator set with capacity x , \bar{x} being it's mean and σ is the standard deviation of the gases .with the dummy variable v for the generator capacity.

For purpose of randomising the generator set capacity, we assume that N that is the total number of generator in the whole community is very large, hence by law of large numbers, x has normal distribution.

The Spread of the emitted gases into the environment can determine using

$$D(x) = (1 - \frac{1}{2} \left[1 - \text{erf} \left(\frac{x}{\sigma\sqrt{2\pi}} \right) \right]) + E(x) \quad (7)$$

$$E_p(x) = N(N-d) \left[1 - \frac{1}{2} \left(1 - \text{erf} \left(\frac{x-x_p}{\sigma_p\sqrt{2\pi}} \right) \right) \right] \quad (8)$$

$$x_p = \sum_{i=1}^N n_i, \sigma_p = \sqrt{\frac{\sum_{i=1}^N (x_i - x_p)^2}{N-1}}$$

Where $D(x)$ is spread function with capacity x ; $E_p(x)$ is the emission function with randomized capacity x , N is the number of generator sets in the whole community with d degree of freedom. x_p the pooled mean for the network of villages linked together and σ_p is the corresponding standard deviation.

4. Results and Discussion

Summarized findings of the emission from generator sets are presented in Table 2.

4.1. Carbon Dioxide Emissions

The overall average carbon dioxide emission averaged was 3.29% with a median value of 3.29% whereas the maximum and minimum values were 3.64 and 3.06%, respectively. The graphical presentations of the CO₂ emissions presented in Figure 2 was highly correlated regression polynomial functions and are represented in the following of order 2 and order 3 respectively:

$$\left. \begin{aligned} y_{CO_2} &= -0.0101x^2 + 0.0742x + 3.2713 \\ y_{CO_2}^{(2)} &= 2.4466 + 0.1533x - 0.0062x^2 \\ y_{CO_2}^{(3)} &= -5.2246 + 1.7771x - 0.1175x^2 + 0.0025x^3 \\ y_{Temp}^{(2)} &= 244.3950 - 10.6535x + 0.3572x^2 \end{aligned} \right\} (9)$$

Where, y_{CO_2} , $y_{CO_2}^{(2)}$, $y_{CO_2}^{(3)}$ are the CO₂ emissions (%); $y_{Temp}^{(2)}$ is the temperature of the exhaust and x is the engine capacity (kVA). $y_{CO_2}^{(2)}$, $y_{Temp}^{(2)}$, $y_{CO_2}^{(3)}$ were obtained using polynomial fitting in the Maple 2017.

Table 1. Generator sets emissions summary

SNO.	CAPACITY, kVA	GENSETS QUANTITY	CO ₂ [%]	CO [mg/nm ³]	NO _x [mg/nm ³]	NO [mg/nm ³]	EXHAUST TEMP. [°C]
1	10.00	3	3.29	473.17	600.67	373.75	172.83
2	12.00	4	3.30	341.69	382.13	237.88	166.38
3	13.00	9	3.57	450.00	418.56	269.03	188.81
4	13.50	3	3.64	398.42	458.50	285.50	159.58
5	14.00	4	3.06	421.06	325.81	202.94	146.81
6	15.00	3	3.46	493.17	298.75	186.17	162.00
7	16.00	31	3.32	342.74	292.69	170.41	158.30
8	16.50	13	3.11	343.81	370.90	224.55	174.31
9	17.00	4	3.12	397.25	526.00	327.63	175.38
10	20.00	26	3.07	425.11	313.98	197.51	171.33
TOTAL:		100					
MEAN			3.29	408.64	398.80	247.53	167.57
MEDIAN			3.30	409.74	376.51	231.21	168.85
MAX.			3.64	493.17	600.67	373.75	188.81
STAND DEV			0.21	54.48	103.14	65.89	11.61
MIN.			3.06	341.69	292.69	170.41	146.81
TANZANIA STANDARD*				175.00	450.00		

* The Environmental Management (Air Quality Standards) Regulations, 2007.

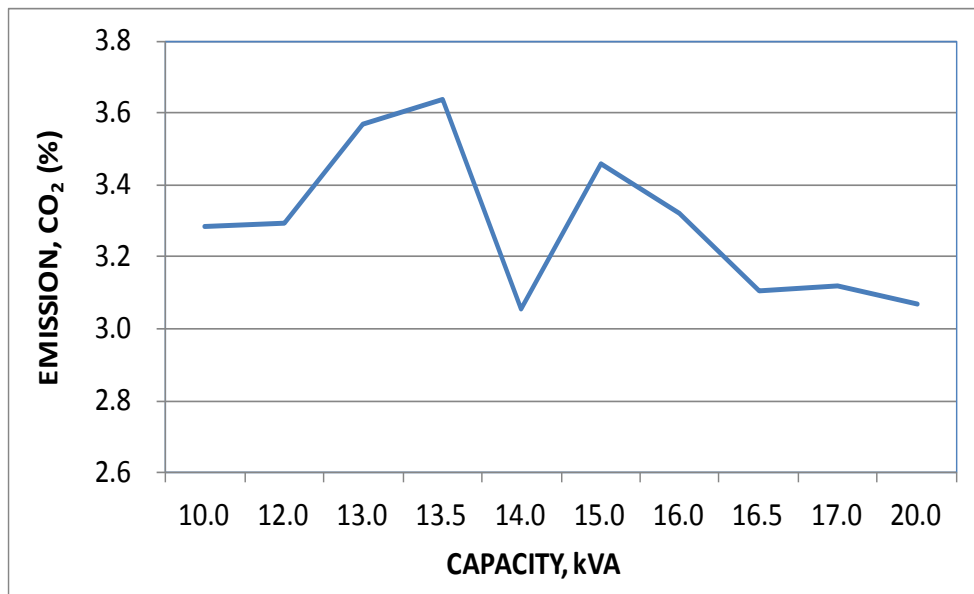


Figure 2. Carbon dioxide emission evolution from generator engines

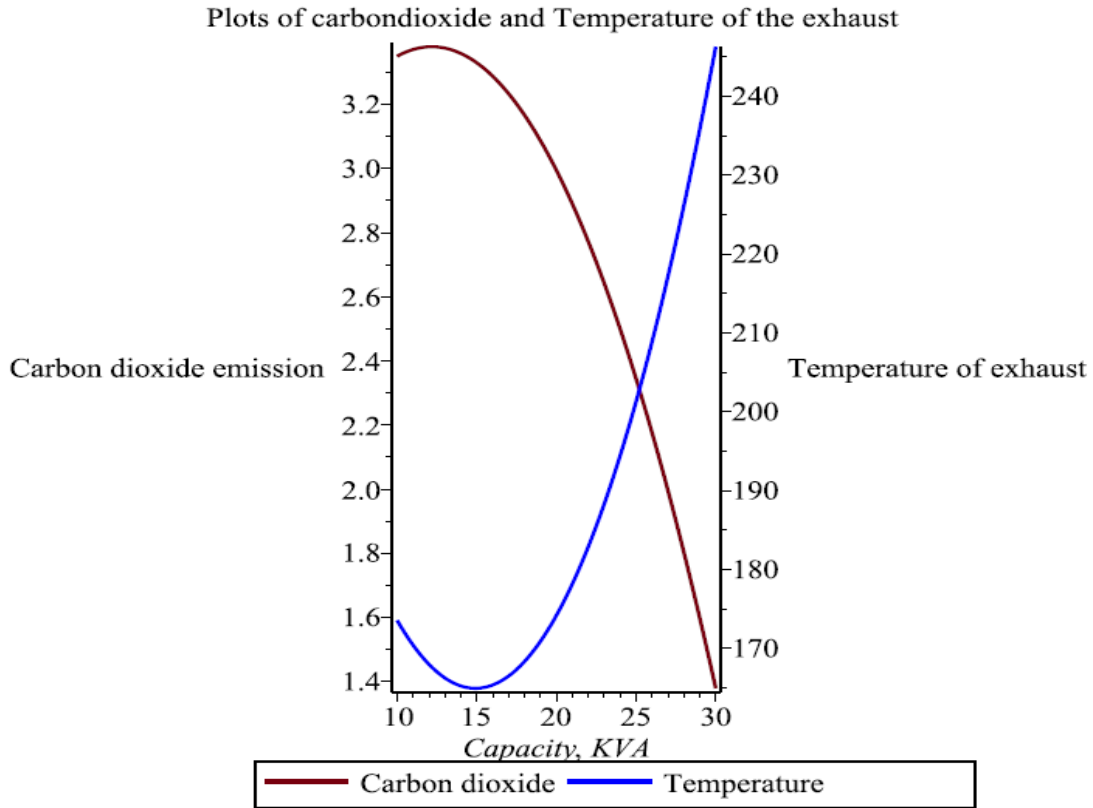


Figure 3. Plots of carbon dioxide and temperature of the exhaust

4.2. Carbon Monoxide Emissions

Details presented in Figure 4 below shows that the average carbon monoxide emission from the studied generator engines averaged 408.64 mg/nm³. The median, maximum, and minimum CO emission values were 409.74, 493.17, and 341.69 mg/nm³, respectively. With comparison with the carbon monoxide threshold standard values for Tanzania Air Quality Standard (2007), all the generator engines are emitting excessive CO emission. The standard has set 175 mg/nm³ as the maximum attainable CO emission.

The CO emission evolution from the studied engines

was fitted to a logarithmic function, Equation (10). However, the emissions were equally well-fitting to a polynomial function presented in equation (9):

$$\left. \begin{aligned}
 y_{CO} &= -19.41\ln(x) + 437.96 \\
 y_{CO} &= 0.7324x^2 - 12.113x + 447.07 \\
 y_{CO}^{(2)} &= 807.6561 - 50.7937x + 1.55x^2 \\
 y_{CO}^{(3)} &= 420.7269 + 31.1096x - 4.0527x^2 + 0.1245x^3
 \end{aligned} \right\} (10)$$

Where, y_{CO} , $y_{CO}^{(2)}$, $y_{CO}^{(3)}$ are the CO emissions (mg/nm³) and x is the engine capacity (kVA).

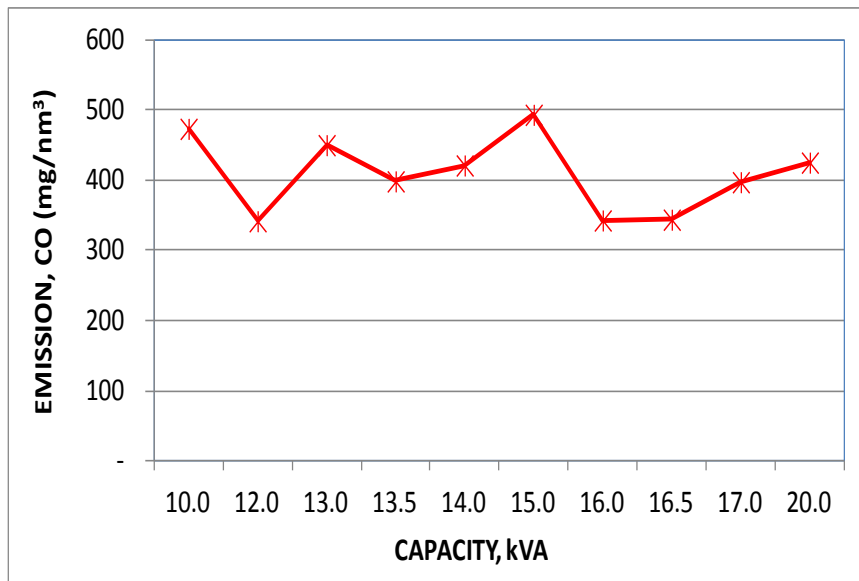


Figure 4. Carbon monoxide emission evolution from generator engines plotted using y_{CO}

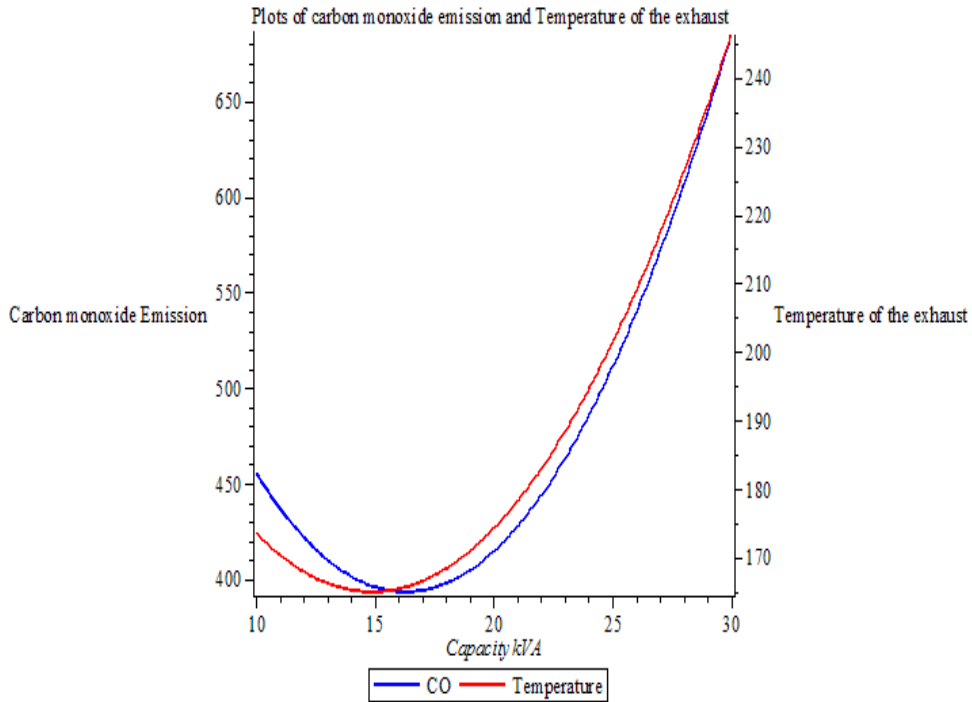


Figure 5. Plot of carbon monoxide emission and exhaust temperature using $y_{CO}^{(2)}$, $y_{Temp}^{(2)}$

4.3. Nitrogen Oxides Emissions

Figure 6 & Figure 7 present the nitrogen oxides evolution from the generator engines. The nitrogen oxides averaged 398.80%. The respective median, maximum, and minimum NOx emission values were 376.51, 600.67, and 292.69%, respectively. The NOx emissions evolution from the engines was fitted to a polynomial function (Equation 11).

$$\left. \begin{aligned} y_{NO_x} &= 6.677x^2 - 87.608x + 623.56 \\ y_{CO} &= 0.7324x^2 - 12.113x + 447.07 \\ y_{NO_x}^{(2)} &= 1490.5164 - 131.9004x + 3.7932x^2 \\ y_{NO_x}^{(3)} &= 6381.7015 - 1167.2431x + 74.7002x^2 - 1.5737x^3 \end{aligned} \right\} (11)$$

Where, y_{NO_x} , $y_{NO_x}^{(2)}$, $y_{NO_x}^{(3)}$ are the NO_x emissions (mg/nm³) and x is the engine capacity (kVA). Where, y is the NO_x emissions (mg/nm³) and x is the engine capacity (kVA).

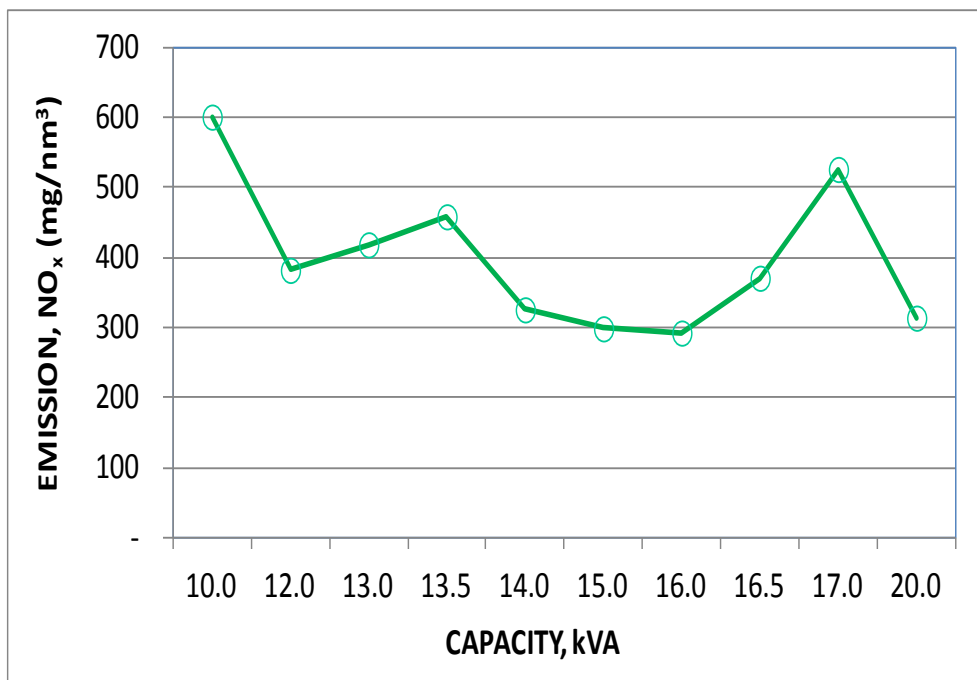


Figure 6. Nitrogen oxides emission evolution from generator engines

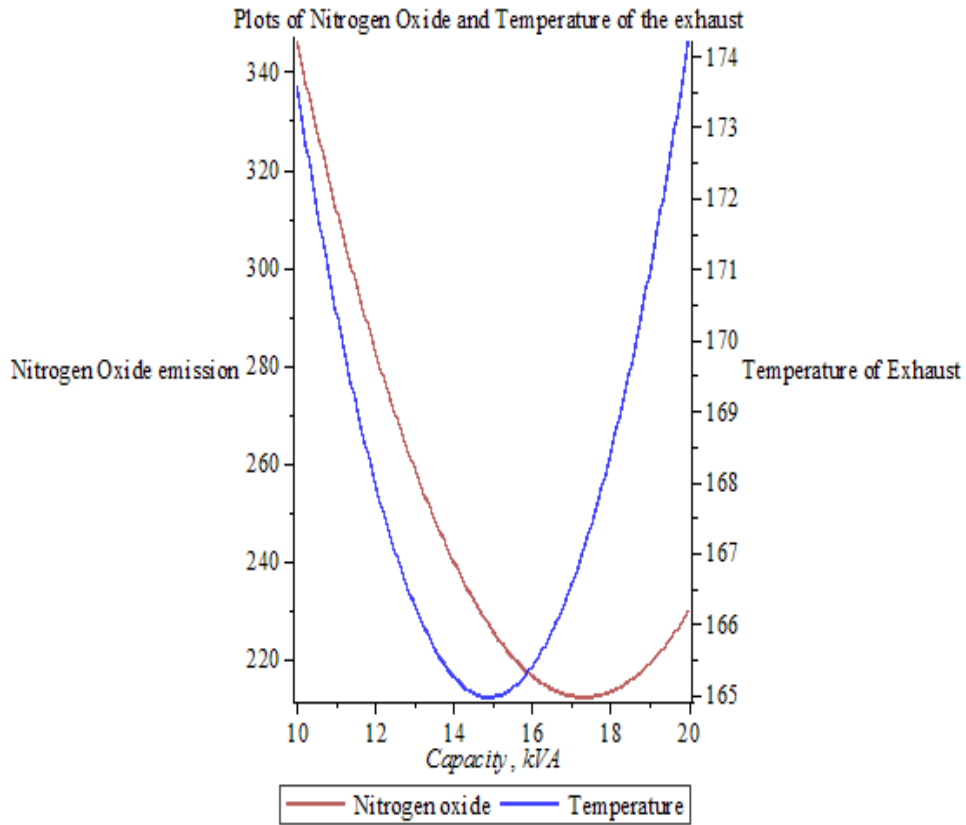


Figure 7. Plot of Nitrogen emission and exhaust temperature using $y_{NO}^{(2)}$, $y_{Temp}^{(2)}$

4.4. Exhaust Gas Temperature

As shown in Figure 8, the generator engines' exhaust gas temperature ranged between 188.81 and 146.81°C with an average temperature of 167.57°C. Lower and higher engines capacity had relatively higher exhaust gas temperatures. This fact was also applicable to the NO_x evolution where it was observed that lower and higher engine capacities emitted more emissions (Figure 8 and Figure 9). This is because thermal NO_x is more pronounced in high temperature combustion systems. Figure 9 is on Nitrogen oxide emission and Exhaust

temperature. The exhaust gas temperature, Nitrogen oxides emissions are best described by a polynomial function, Equation 12.

$$\left. \begin{aligned} y_{Temp} &= 0.7442x^2 - 8.2569x + 184.33 \\ y_{NO_x}^{(2)} &= 1490.5165 - 131.9004x + 3.7932x^2 \\ y_{NO_x}^{(3)} &= 6381.7016 - 1167.2430x + 74.7002x^2 - 1.5737x^3 \end{aligned} \right\} (12)$$

Where, y is the NO_x emissions (mg/nm³) and x is the engine capacity (kVA).

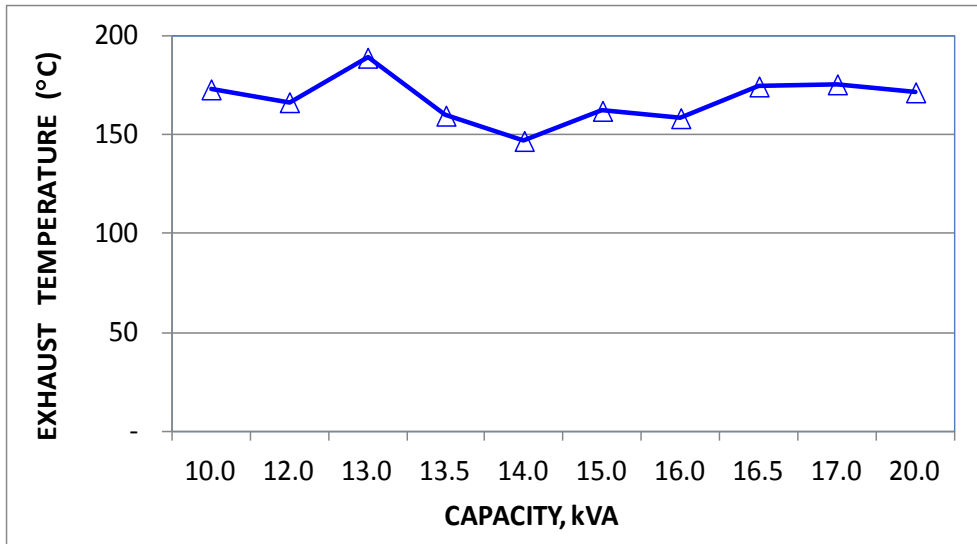


Figure 8. Generator engines' exhaust gas temperature

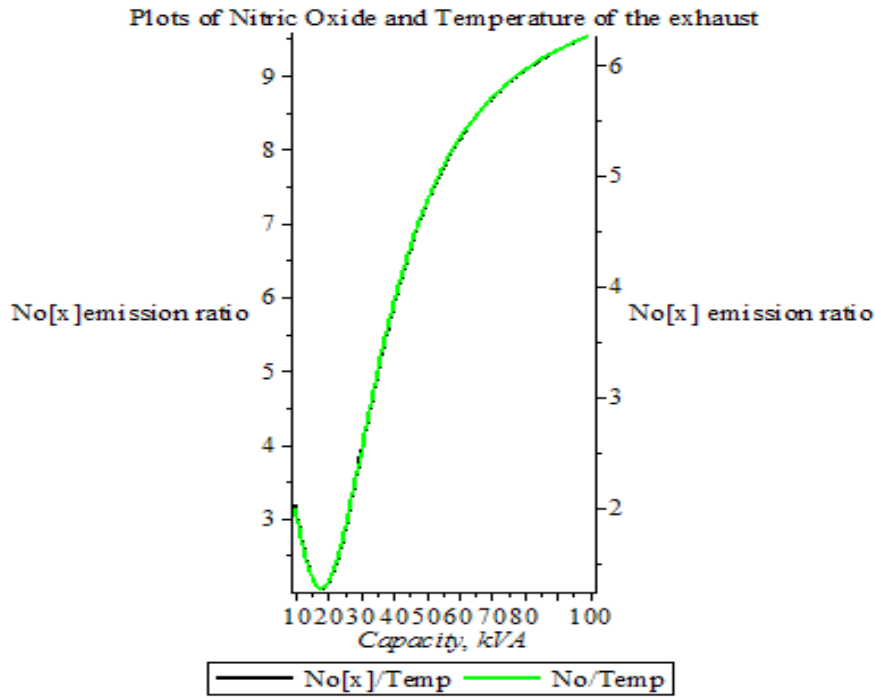


Figure 9. Nitrogen oxide emission and Exhaust temperature

We consider 10 random samples from the normal distribution with the mean 3.29 and variance 1. we make use the random number generator in the Maple 2017 software using the code:

```
> u := Sample(Normal(3.29, 1), 10);
```

$$u = \begin{bmatrix} 2.2176 & 2.9609 & 2.6729 & 3.504 & 3.2646 \\ 5.0188 & 1.655 & 4.8612 & 3.4604 & 4.2965 \end{bmatrix}$$

Where / is the transpose of the vector .Then define the sequence $T_i = w_i + u_i$ and $T = \{T_i\}_{i=1,2,\dots,10}$. Therefore,

$$T = \begin{bmatrix} 602.8875 & 385.0909 & 421.2329 & 462.0045 & 329.0745 \\ 303.7688 & 294.3451 & 375.7611 & 529.4603 & 318.2765 \end{bmatrix}$$

Using the point plot facility in the Maple 2017 we plotted $G = Q_i + u_i$ together with T and we have the plots in the Figure 10.

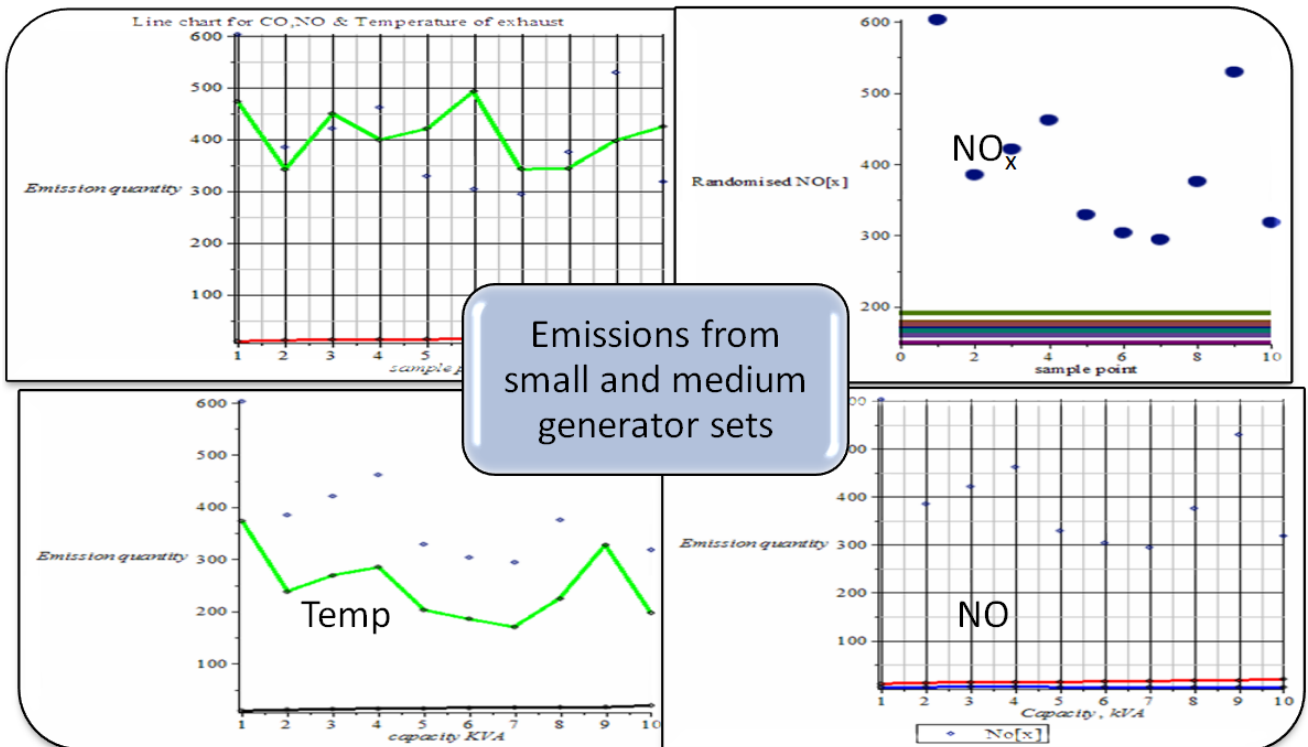


Figure 10. Emission Co, No, NOx and Temperature for small and medium generator sets

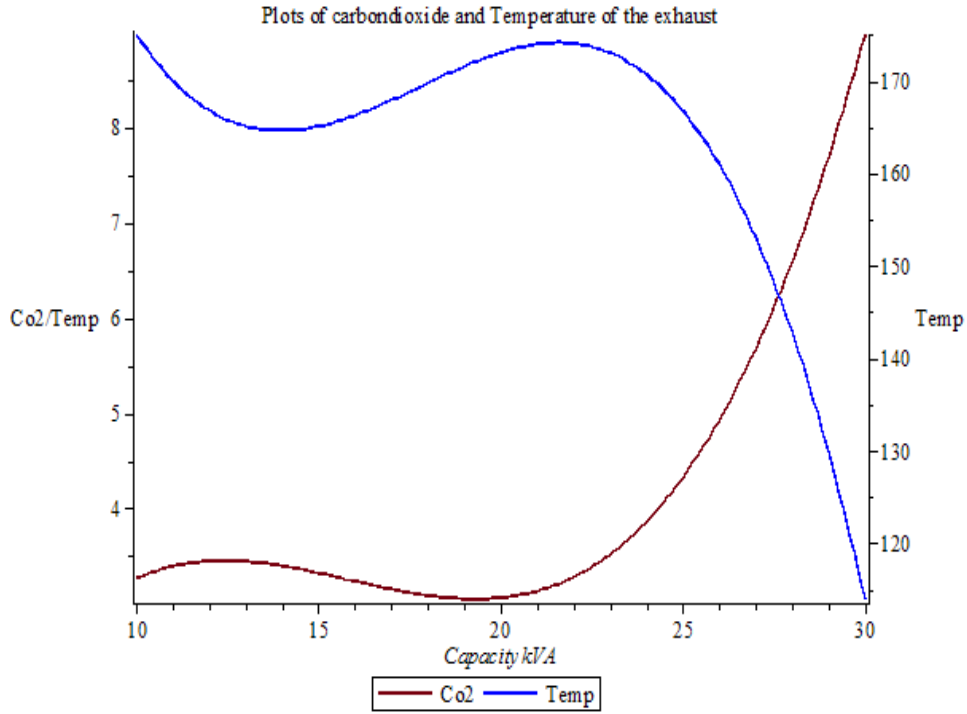


Figure 11. Carbon dioxide and Temperature of exhaust

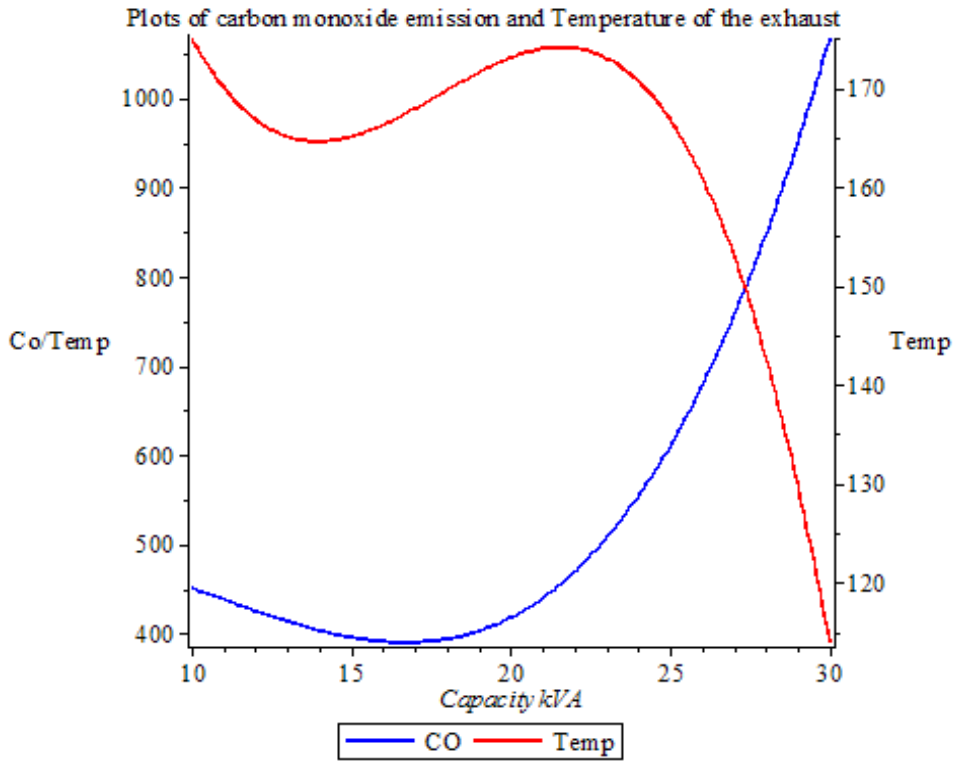


Figure 12. Carbon monoxide and Temperature of exhaust

In the Figure 11, dual axis plot is made for carbon dioxide in red colour against temperature in in blue colour. In the Figure 12, dual axis plot is made for carbon monoxide in blue colour against temperature in in red colour.

We obtain asymptotic expansion of ratio of carbon dioxide and Nitrogen oxide (NO_x) against temperature of the exhaust as follows:

$$\left. \begin{aligned}
 y \frac{Co_2}{Temp} &= \left(\frac{0.0574 + \frac{0.3300}{x} + \frac{26.9653}{x^2}}{\frac{455.6454}{x^3} + \frac{20906.6603}{x^4} + \frac{7.6243}{x^5}} \right) + O\left(\frac{1}{x^6}\right) \\
 y \frac{No_x}{Temp} &= \left(\frac{20.1893 + \frac{109.7748}{x} + \frac{2865.1372}{x^2}}{\frac{1.4584}{x^3} + \frac{6.1526 \times 10^6}{x^4} + \frac{2.2143 \times 10^8}{x^5}} \right) + O\left(\frac{1}{x^6}\right)
 \end{aligned} \right\} \quad (13)$$

We propose two models for emission CO₂ as function temperature of the exhaust T and generator set capacity x as follows:

$$y_{\frac{CO_2}{Temp}}(x,T) = \left(\left(0.0574 + \frac{0.3300}{x} + \frac{26.9653}{x^2} + \frac{455.6454}{x^3} + \frac{20906.6603}{x^4} + \frac{7.6243}{x^5} \right) (T-273) \right) \quad (14)$$

$$y_{\frac{CO_2}{Temp}}^{(2)}(x,T) = \left(\begin{aligned} &0.0574(T-273) + \frac{0.3300}{x}(T-273)^2 + \frac{6.9653}{x^2}(T-273)^3 \\ &+ \frac{455.6454}{x^3}(T-273)^4 + \frac{20906.6603}{x^4}(T-273)^5 + \frac{7.6243}{x^5}(T-273)^6 \end{aligned} \right)$$

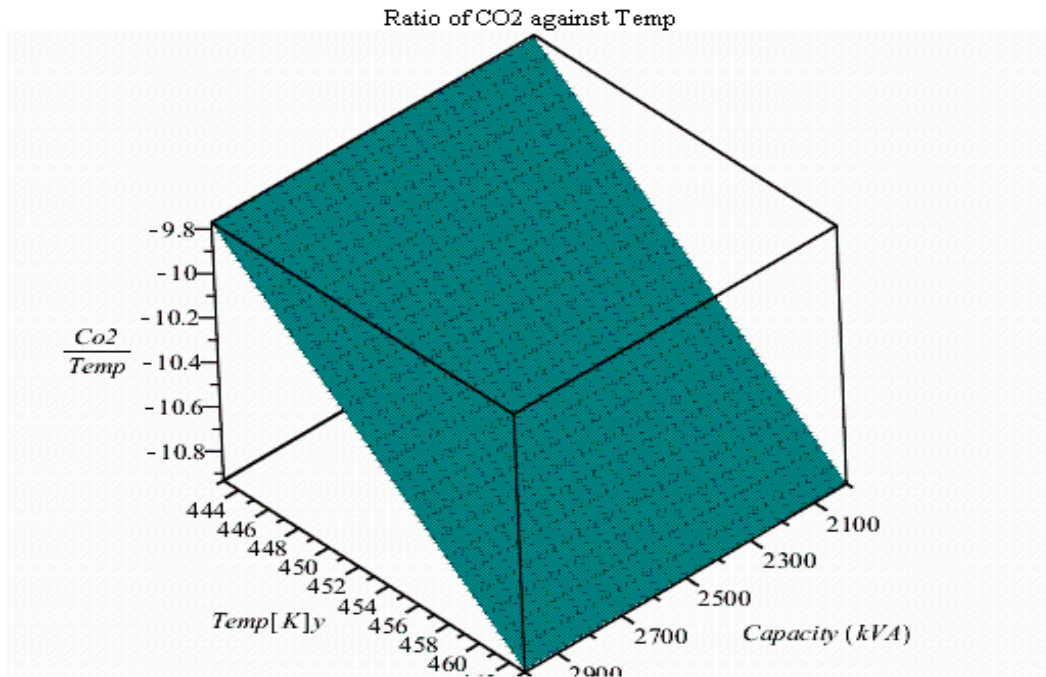


Figure 13. Ratio of Carbon dioxide to exhaust Temperature

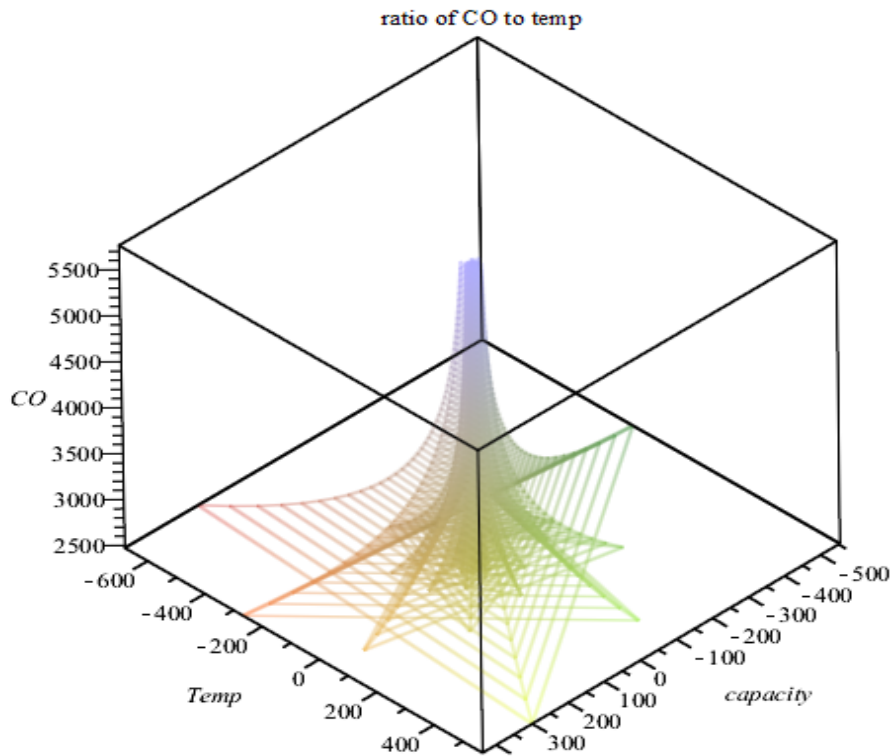


Figure 14. Ratio of Carbon monoxide to exhaust Temperature

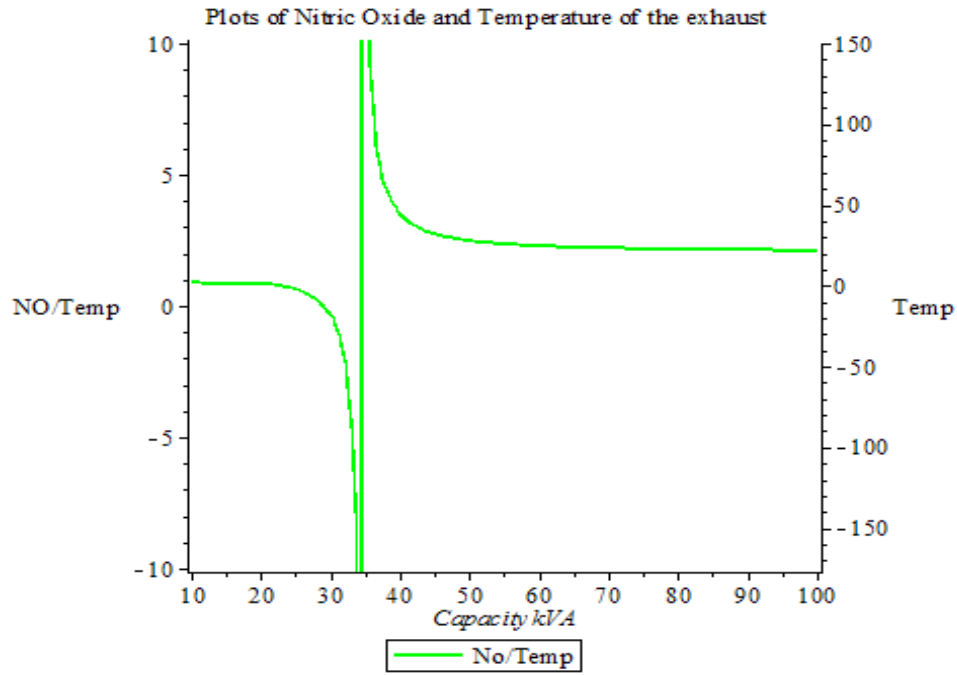


Figure 15. Nitrogen oxide against exhaust temperature

3D Ratio of Nitrogen oxide to Temperature against generator capacity

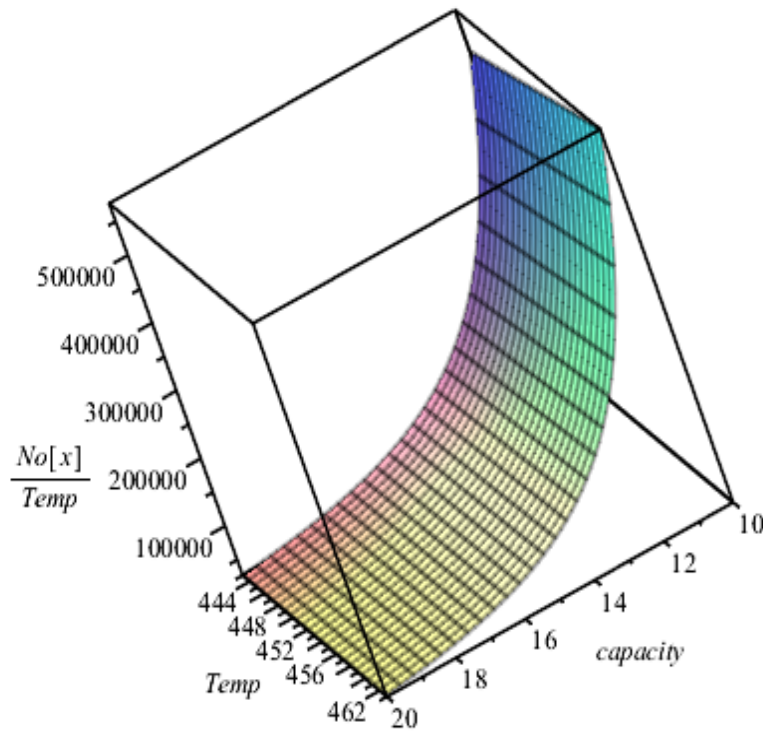


Figure 16. 3 D plot of Nitrogen oxide against exhaust temperature

$$\left. \begin{aligned}
 \frac{y}{Temp} \frac{No_x}{Temp} &= \left(20.1893 + \frac{109.7748}{x} + \frac{2865.1372}{x^2} + \frac{1.4584}{x^3} + \frac{6.1526 \times 10^6}{x^4} + \frac{2.2143 \times 10^8}{x^5} \right) (T-273) \\
 \frac{y}{Temp} \frac{No_x}{Temp} &= 20.1893(T-273) + \frac{109.7748}{x}(T-273)^2 + \frac{2865.1372}{x^2}(T-273)^3 \\
 &\quad + \frac{1.4584}{x^3}(T-273)^4 + \frac{6.1526 \times 10^6}{x^4}(T-273)^5 + \frac{2.2143 \times 10^8}{x^5}(T-273)^6
 \end{aligned} \right\} \quad (15)$$

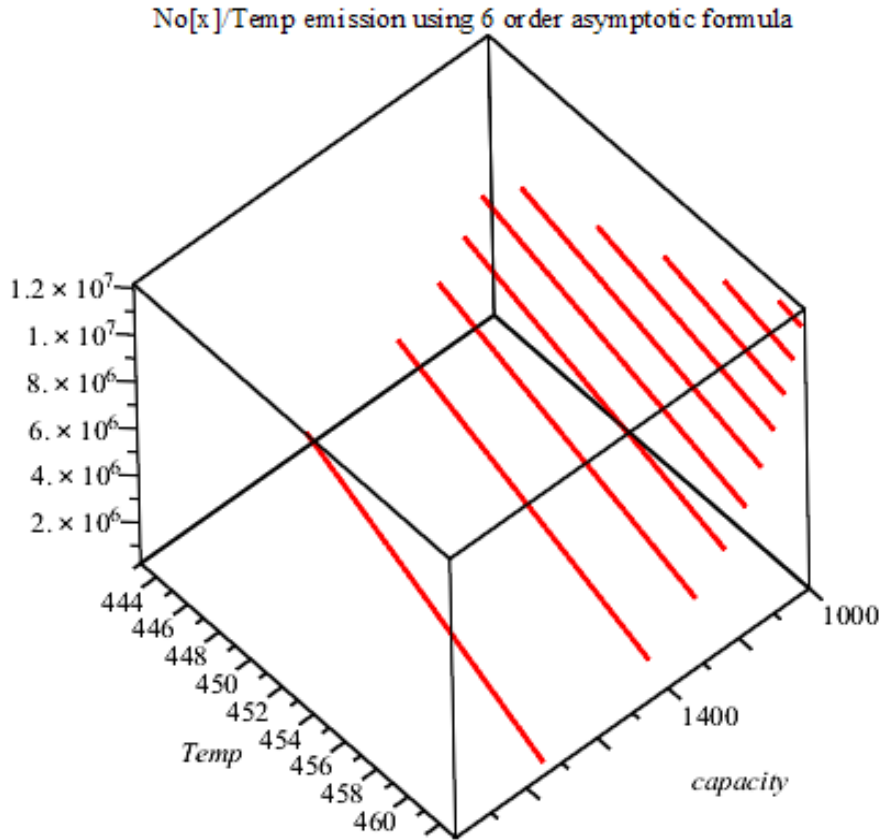


Figure 17. Ratio of NO_x to exhaust Temperature

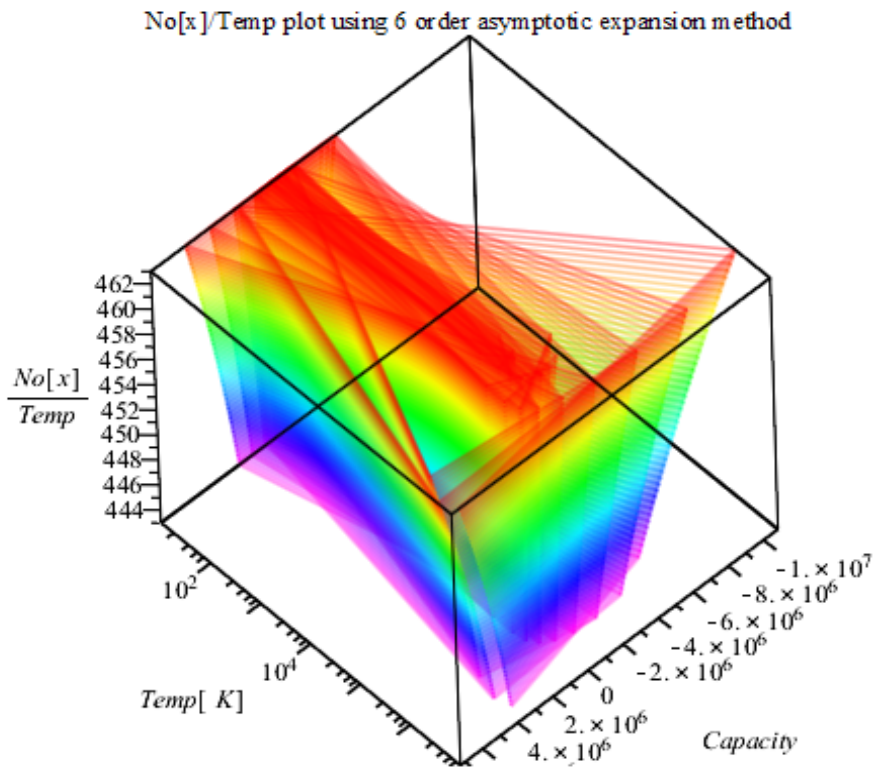


Figure 18. Asymptotic plot of ratio NO_x to exhaust temperature

Nitrogen oxide emission is very high for large capacity generator set. This is because the temperature of the exhaust is extremely high which leads to nitrogen in the air combining with oxygen to produce nitrogen oxide gases and the nitrogen in the hydrocarbon fuel together

with impurities in it produces NO_x at the high temperature zone of the exhaust. The surround of the exhaust is often brownish in colour. This brownish colour is characteristic high temperature emission of NO_x when rocket and missiles are fired.

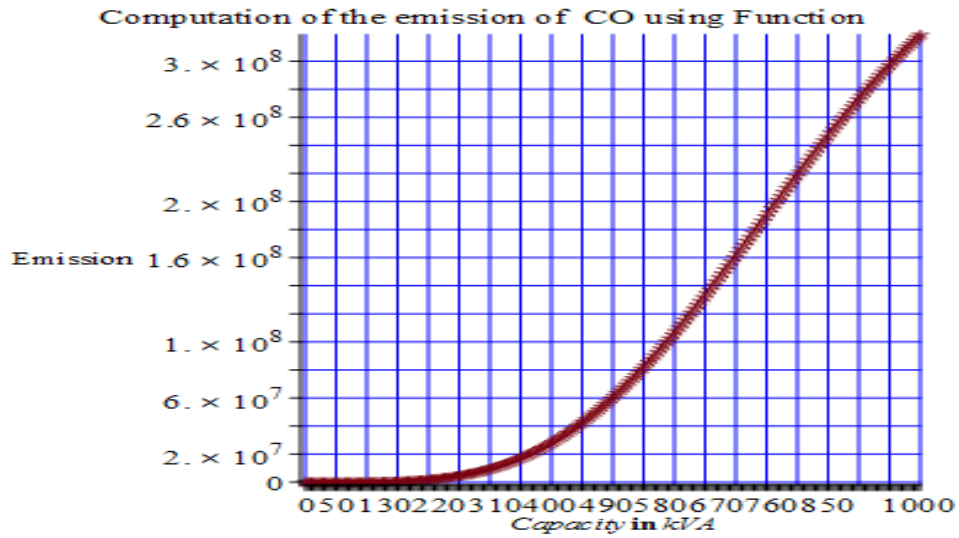


Figure 19. Graph emission spread for CO

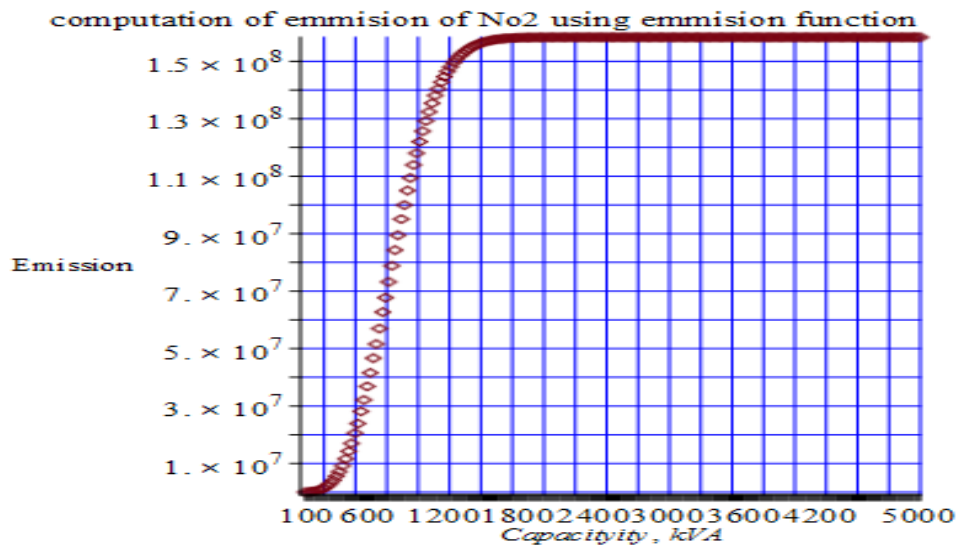


Figure 20. Emission of NO₂

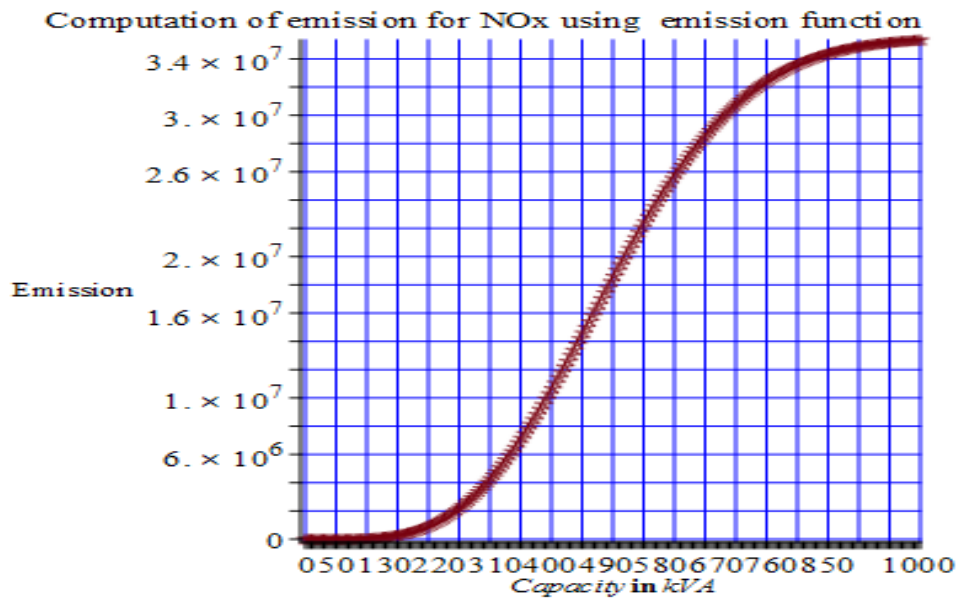


Figure 21. Emission of NO_x

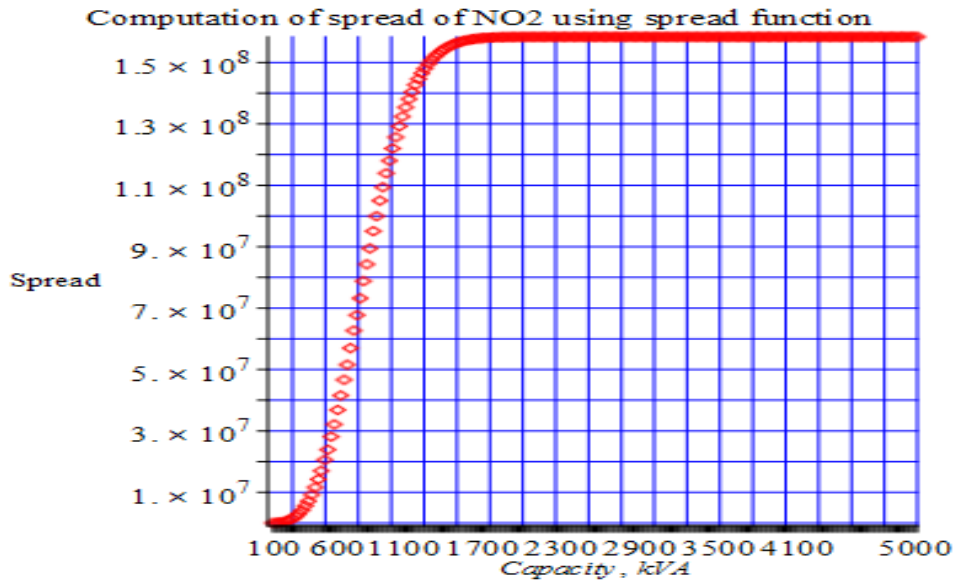


Figure 22. Spread of Nitrogen oxide to the surrounding

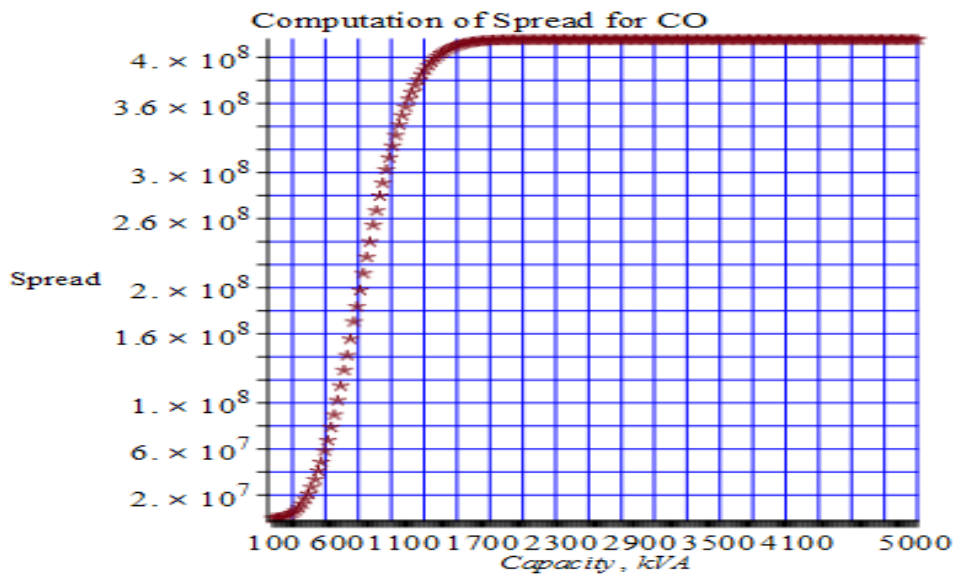


Figure 23. Graph emission spread for CO

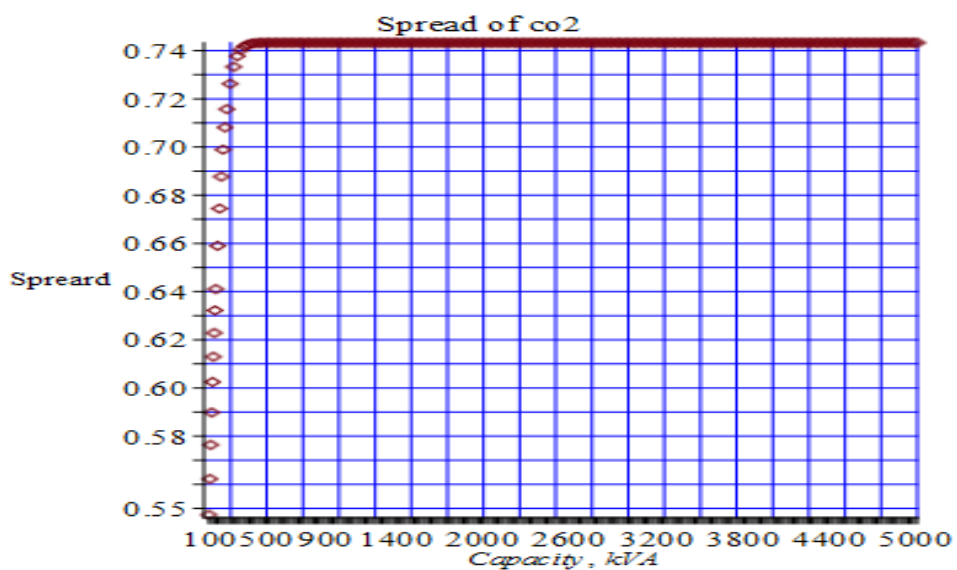


Figure 24. Emission of CO2

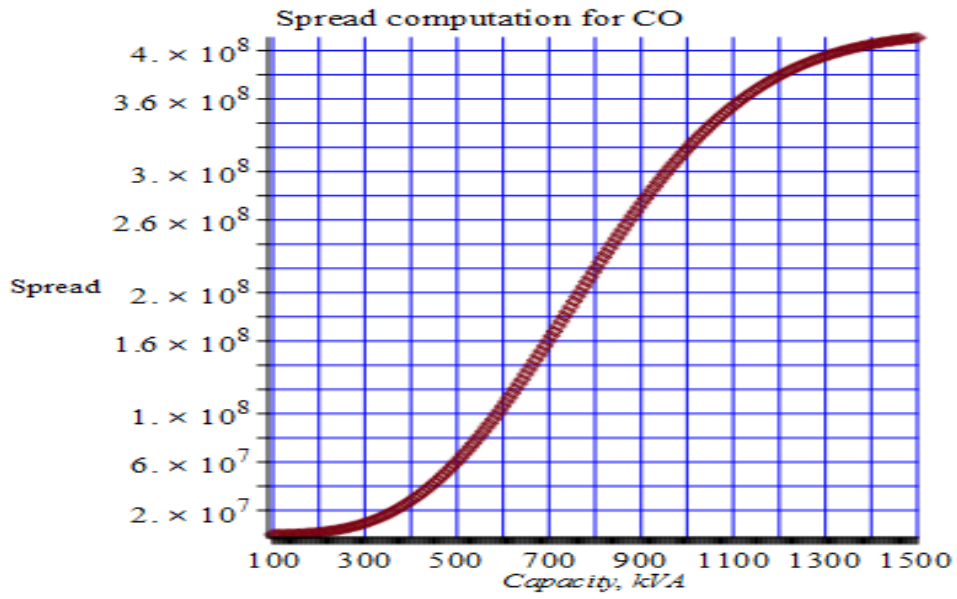


Figure 25. Spread of carbon monoxide

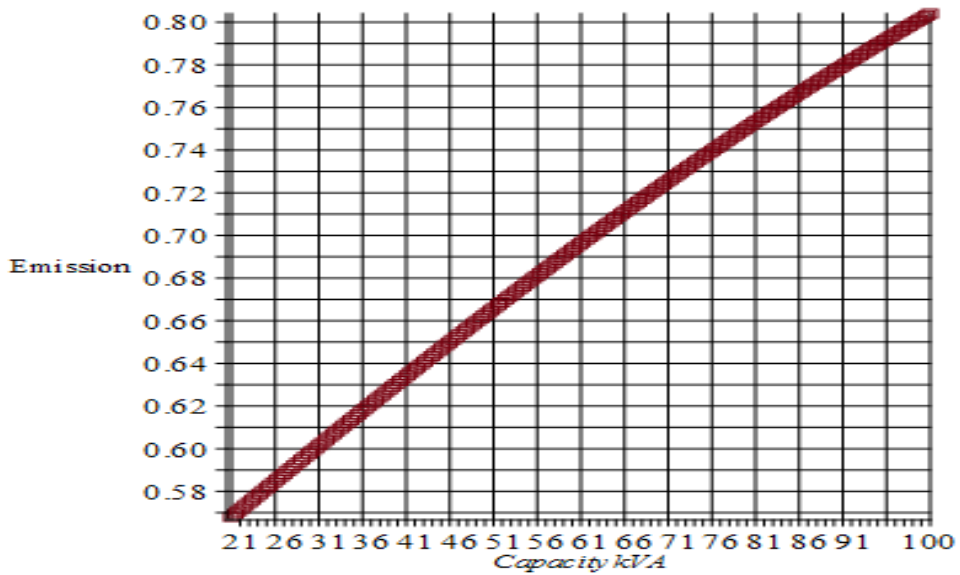


Figure 26. Emission of carbon monoxide to the surrounding

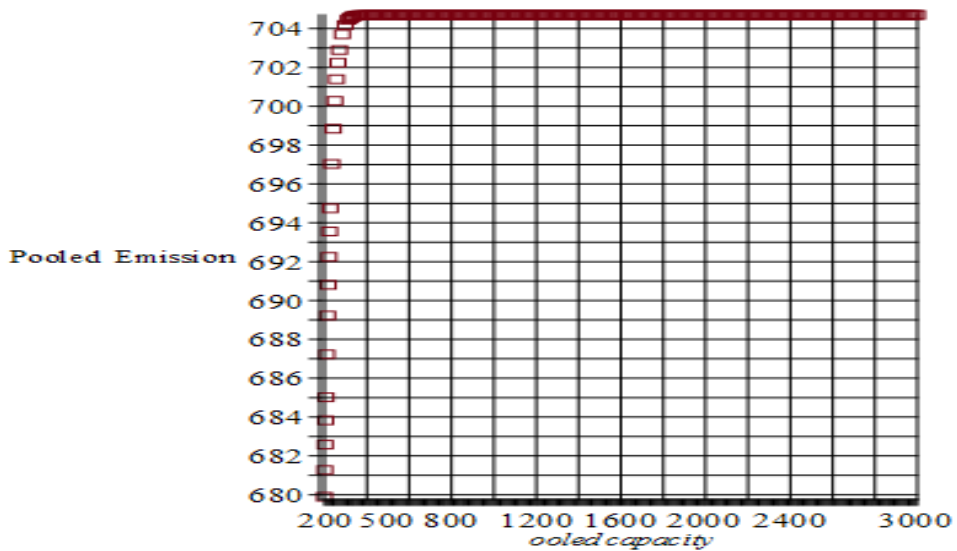


Figure 27. Emission from network of sources

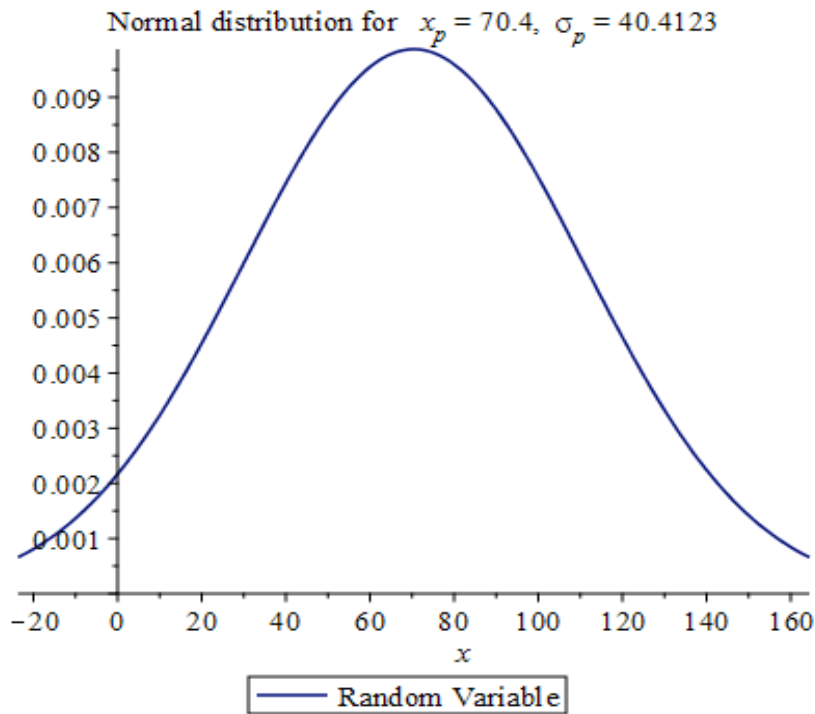


Figure 28. Normal distribution for the small community with pooled mean $x_p = 70.4$ and pooled standard deviation $\sigma_p = 40.4123$

Figure 19 – Figure 26 are the plots of emission and spread of CO, CO_2 & NO_x respectively. The spread of carbon monoxide (see Figure 19 & Figure 23) and the emission of NO are sigmoid in nature (see Figure 21). From Figure 19 – Figure 26 we note that the emission of CO, CO_2, NO_x and CO_2 increases with capacity and remain constant for ($x > 1700$ for NO_x), ($x > 1800$ for NO_2), ($x > 1700$ for CO), and spread for ($x > 500$ for CO_2).

The average memory space for the simulation 39.373M and simulation time of 0.255 and average simulation time spread function is 20mins.

5. Conclusion

The Carbon monoxide, Carbon dioxide and Nitrogen oxides emission data from 100 small and medium generator sets with capacity ranging from 10 to 20 kVA are obtained from portable combustion gas analyzer using KAN90PLUS model. Two models are proposed to study the emission of gases from the exhaust of the generator sets. We also proposed emission and spread function to analysis pollution of the environment from burning fossil fuel by the generator sets. From our finding large quantity of CO, CO_2, NO_x are being emitted by the generators sets and this will have serious effect on the air quality in the remote environment where small and medium size generator sets are being used for generating electricity. The agricultural productive of the community will also be affected because of acid rain in that environment couple with allergic and respiratory diseases because of emission of the poisonous gases to the remote environment.

As a policy, generator sets with low emission such as those whose exhausts have monocatalytic beds should be allowed into the developing country.

Conflict of Interest

The authors declare no conflict of interest.

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