- June 2017
- DOI : 10.1109/PowerAfrica.2017.7991214
- Conference: 2017 IEEE PES/IAS PowerAfrica

Diesel Engine Generators Consumption/Emission Controls by Retrofitting for Sustainable Environment

Aderibigbe M.A, Wara, S.T, Airoboman A.E.
Department of Electrical and Information Engineering
Covenant University, Ota, Nigeria
aderibigbeadeleke@yahoo.com

Abstract - Diesel Engine Generators (DEGs) are used to generate power but consequently produce emissions of toxic air pollutants such as Particulate Matter (PM) and Oxides of Nitrogen (NOx) which are harmful to humans and the environment. This paper has investigated the effect of retrofitting a 15kVA DEG using Retrofitted Diesel Fuel (RDF) and Pure Diesel Fuel (PDF). The data obtained were analysed sequentially using simple percentages and the result interpreted graphically with the aid of spread sheet. By retrofitting there was a 71% reduction in PM emission, 4% reduction in NOx emission and 28.9% reduction in fuel consumed when RDF was used. By retrofitting there was economic saving due to reduction in fuel consumed and a reduction in the emissions into the environment. Hence, there is an improvement in climate change, ozone depletion and global warming that have remain a threat due to emissions from DEG given rise to a sustainable environment.

Keywords: DEG, PM, NOx, Retrofitting, Fuel consumption, Sustainable environment.

I INTRODUCTION

A DEG is a combination of a diesel engine, a generator and various ancillary devices. DEGs are used routinely to supply electrical power for industrial, commercial and residential consumers during blackouts. Many of these DEGs are being rapidly installed with minimal concern for Environmental Protection Agency (EPA) in U.S and Federal Environmental Protection Agency in Nigeria (FEPA) permissions but focussing exclusively on providing backup power to avoid blackouts (either scheduled or unscheduled). The net effect of these events should be an increase in air pollutants as these DGS are brought online. [1]. Diesel engine generators are reliable, fuelefficient, high-torque engines, easy to repair, inexpensive to operate and extremely durable which power many of the world's heavy-duty trucks, buses, off-road vehicles and generators. Hence it is common for a diesel engine to last 15-20 years and achieved a one million-mile life [2]. In the state of Alaska alone, there are approximately 200 diesel-powered communities [3]. However, DEGs emit toxic air pollutants PM and NOx that pollute the air in which health experts have concluded that pollutants emitted by diesel engines adversely affect human health and contribute to acid rain, ground-level ozone, and reduced visibility [4]. Long term exposure to PM is highly dangerous since it is associated with an increase in the long term risk of cardiopulmonary mortality by 6-13% per $\mu g/m^3$ [5]. Also, the black carbon part of PM which results from incomplete combustion has detrimental effects on health as well as on climate [6]. Studies have shown that exposure to diesel exhaust causes lung damage and respiratory problems and there is increasing evidence that diesel emissions may cause cancer in humans [7]. Hence the need to reducing air pollution from the in-use diesel generators by developing a large portfolios of retrofit emission control devices such as Diesel Oxidation Catalyst (DOC), Selective Catalytic Reduction (SCR), Exhaust Gas Recirculation (EGR) and Xtreme Fuel Treatment (XFT) [8] which will reduce the entire range of regulated and unregulated harmful emissions. Therefore, Xtreme Fuel Treatment (XFT) as a retrofit is chosen to case study these pollutants from the DEGs.

II METHODOLOGY

Diesel engine generators are very important in maintaining production or activities flow in case of utility power failure. They however come with emission of pollutants which are dangerous to the environment and therefore, in order to reduce these pollutants, many retrofitting options were considered and Xtreme Fuel Treatment (XFT) was chosen and used. A 15kVA sound proof diesel generator was also used in this study. Two 23 litres of transparent and calibrated jerry cans were used. Each was filled up with diesel fuel: one with additive of 10ml of xtreme fuel treatment (RDF) and the other without additive (PDF). The experiment was conducted first with PDF on the generator on full load without any variable manipulation in the first three hours. The second experiment was performed with RDF also on full load after a cooling period of two hours for the next three hours. The data obtained on both cases were analysed sequentially using simple percentages and the result interpreted graphically with the aid of spread sheet. Conclusions were made based on the assessment of the two experiments.

Table: 1 Readings with Diesel at Full Load (Controlled Model)

Period	Run Time (min)	Amb. Temp. ^0F	SO2 (ppm)	Pure PM (mg/m3)	O2 (%)	CO (ppm)	CO2 (%)	NOx (ppm)
9:45	30	110.4	24	0.648	11.32	105	6.95	302.2
10:15	60	107.4	37	0.459	11.72	91	6.68	318.6
10:45	90	100.5	34	0.503	11.86	93	6.67	315.4
11:15	120	101	34	0.254	11.89	86	6.71	312.3
11:45	150	96.2	35	0.17	11.84	88	6.77	319.0
12:15	180	94.7	31	0.196	11.95	89	6.59	303.9

Table: 2 Readings with Diesel plus additive at Full Load (Retrofitted Model)

Run Time (min)	Amb. Temp. ^0F	SO2 (ppm)	PM (mg/m3)	O2 (%)	CO (ppm)	CO2 (%)	Nox (ppm)
30	97.6	34	0.227	11.24	94	7.02	314.6
60	93.4	37	0.049	11.75	89	6.66	317.5
90	93.5	42	0.108	11.83	92	6.62	307
120	82.5	31	0.106	12.78	89	5.94	282.6
150	80.9	31	0.117	12.68	97	6.02	284.4
180	80.2	34	0.037	12.72	83	5.99	298.6

Table: 3 Reading Diesel Consumption Rate at Full Load (Both Models)

S/N	Run Time (min)	Pure Diesel (liters)	Diesel with XFT	Temp. Pure diesel	Temp. diesel+XFT	Remark
1	0	23	23	48	48	nat start
2	30	0.8	0.46	48	80	0.34
3	60	1.2	0.86	78	80	0.34
4	90	0.93	0.73	80	80	0.2
5	120	1.26	0.96	80	70	0.3
6	150	0.73	0.5	80	72	0.23
7	180	1	0.7	80	75	0.3

The data collated was analysed sequentially using percentages and the result interpreted graphically with aid of spread sheet.

$$bi = \frac{\times pi - \times ri}{\times pi} \times 100\%$$

$\times_{pi}$ = $Average\ value\ of\ particular\ Emission/Consumption\ based\ on\ Pure\ Diesel$

$\times_{ri}$ = $Average\ value\ of\ particular\ Emission/\ Consumption\ based\ on\ retrofitted\ Diesel$

$bi = 0 \le i \le 3$;

When i = 0 ⟶ Percentage Reduction in PM

When i = 1 ⟶ Percentage Reduction in NOx

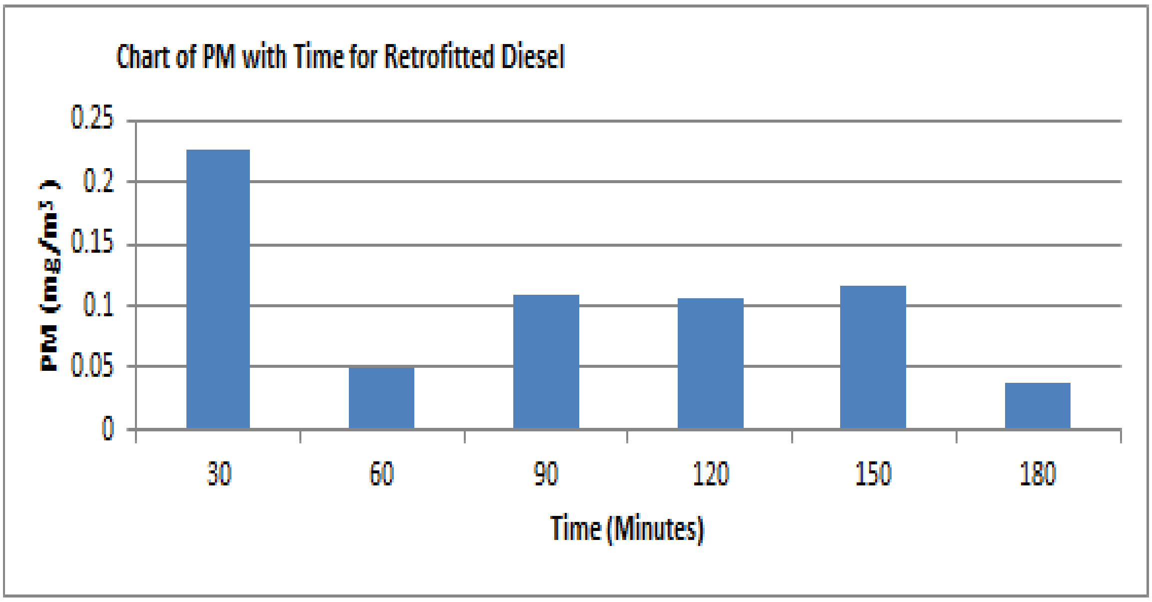

Fig. 1: Graph of PM emission with Time for Retrofitted Diesel

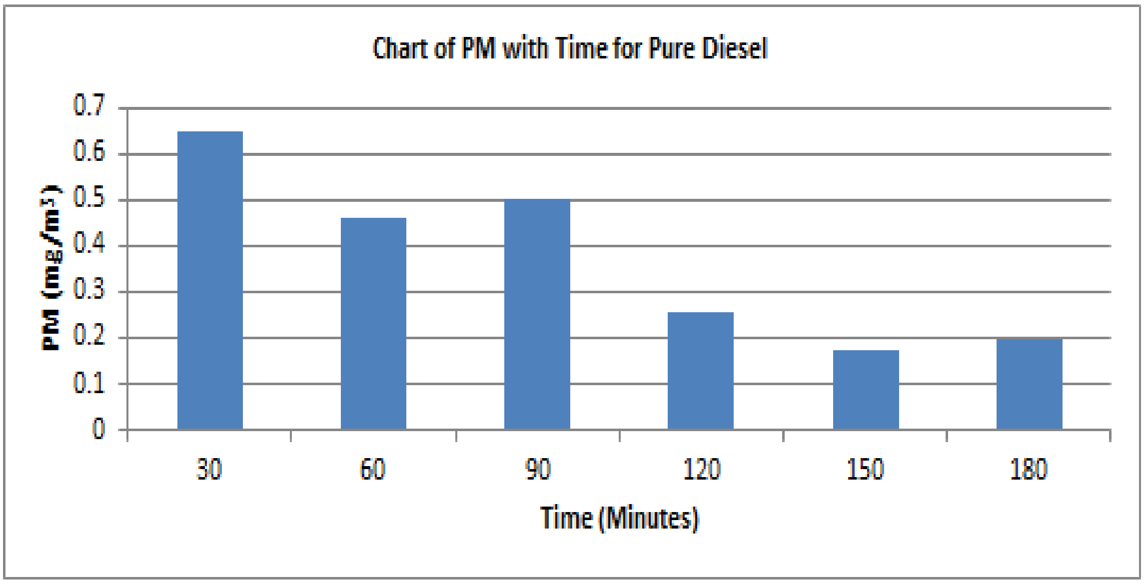

Fig. 2: Graph of PM emission with Time for Pure Diesel

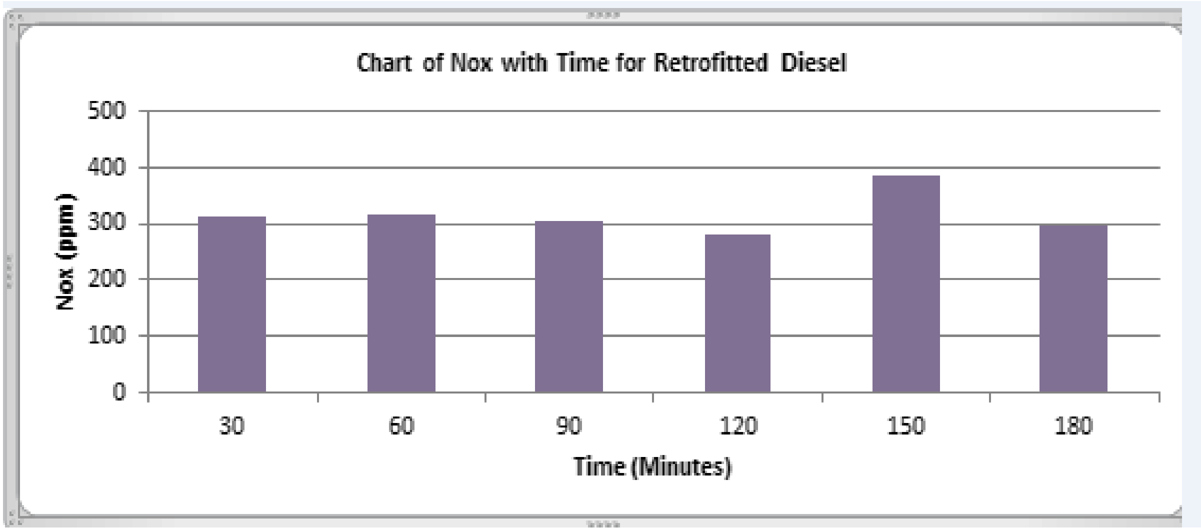

Fig. 3: Graph of NOx Emission with Time for Retrofitted Diesel

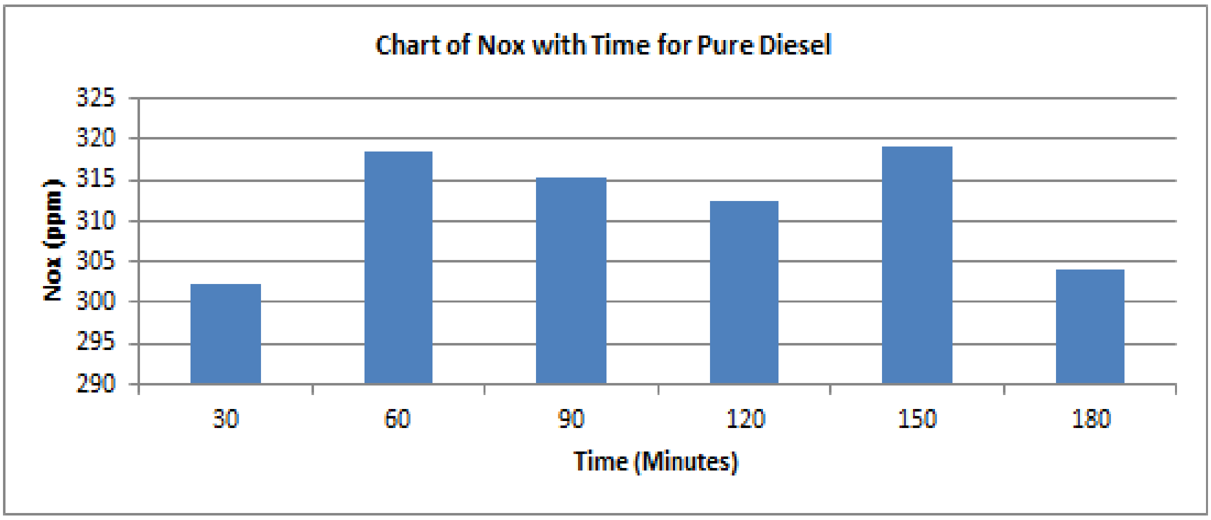

Fig. 4: Graph of NOx Emission with Time for Pure Diesel

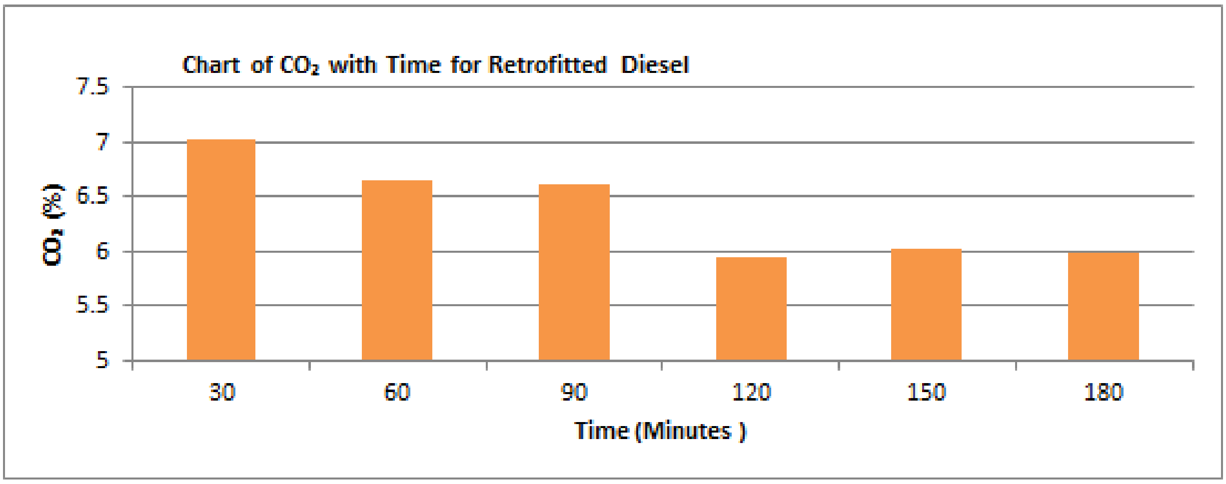

Fig. 5: Graph of CO_2 Emission with Time for Retrofitted Diesel

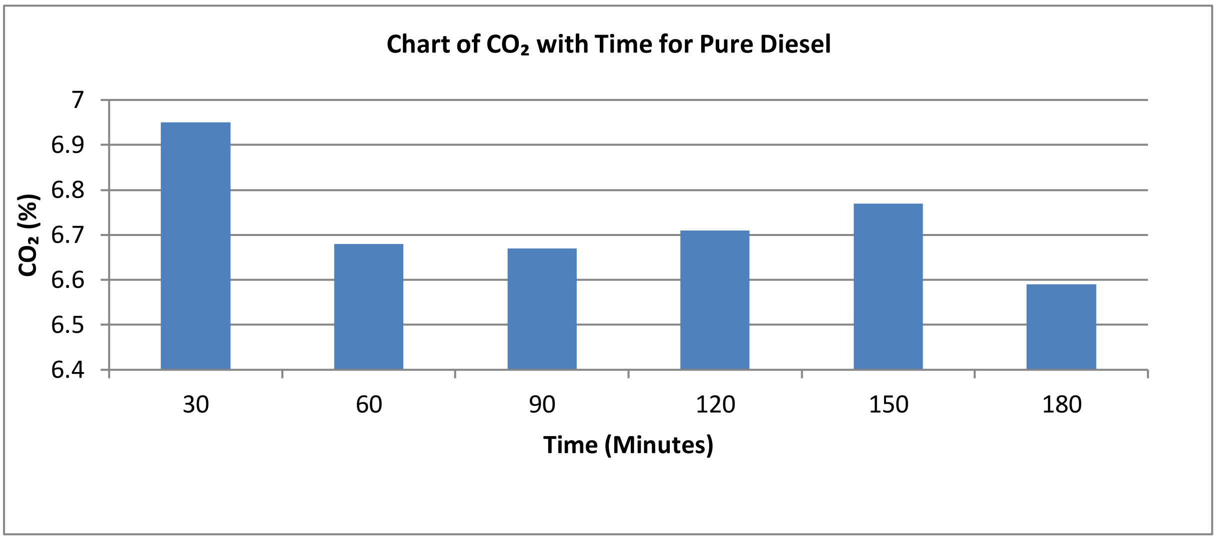

Fig. 6: Graph of CO_2 Emission with Time for Pure Diesel

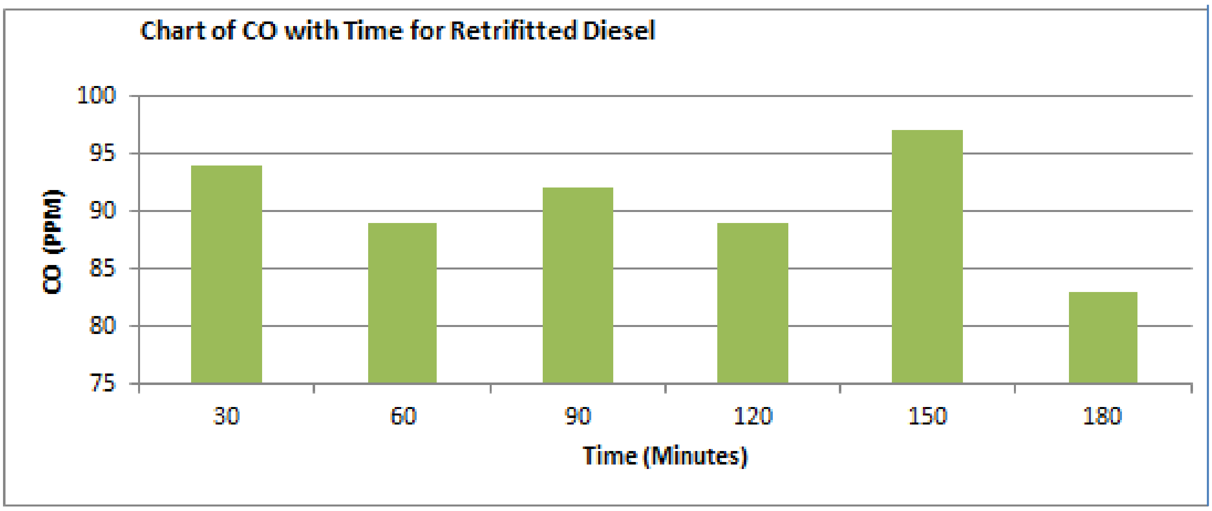

Fig. 7: Graph of CO Emission with Time for Retrofitted Diesel

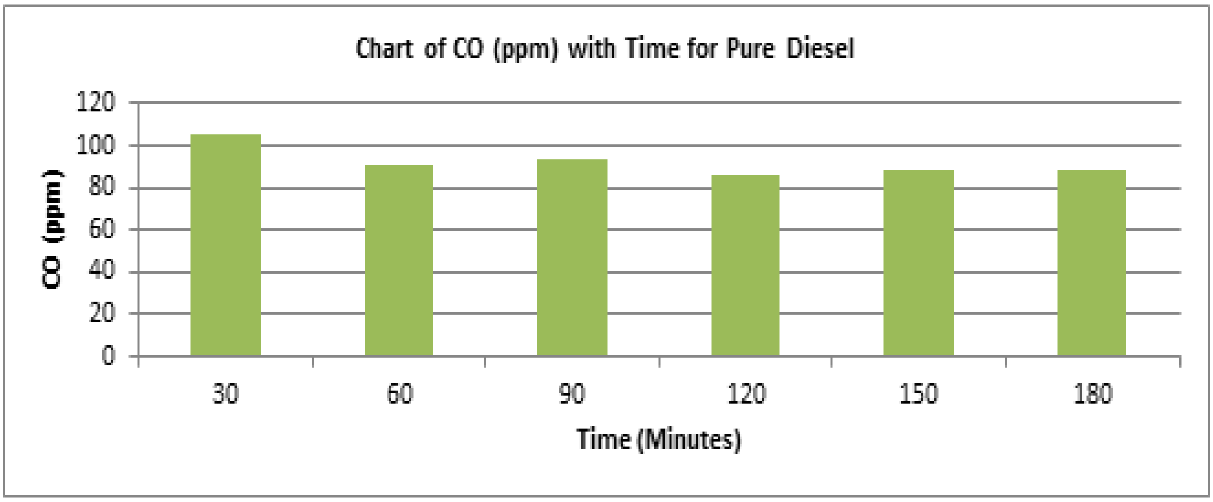

Fig. 8: Graph of CO Emission with Time for Pure Diesel

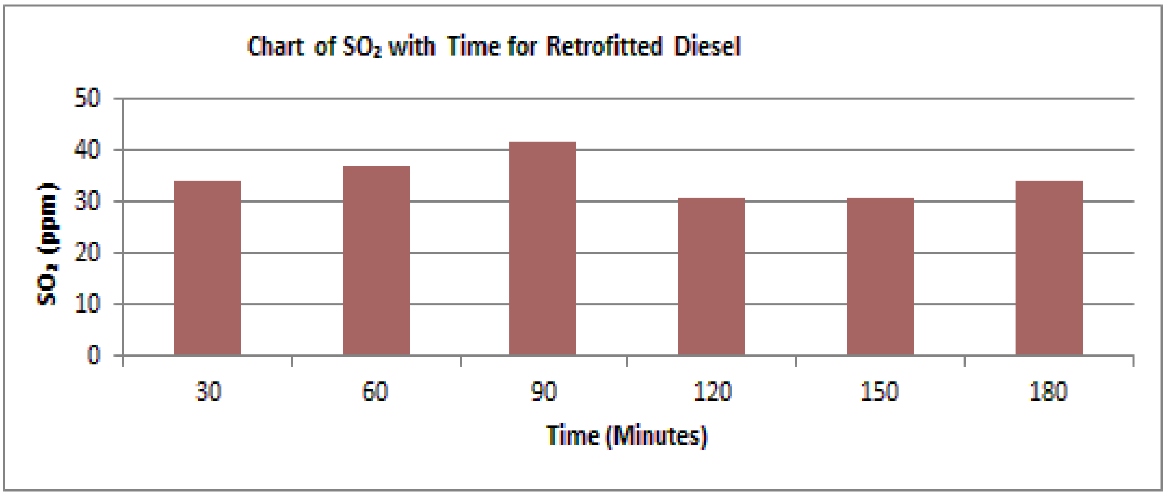

Fig. 9: Graph of SO_2 with Time for Retrofitted Diesel

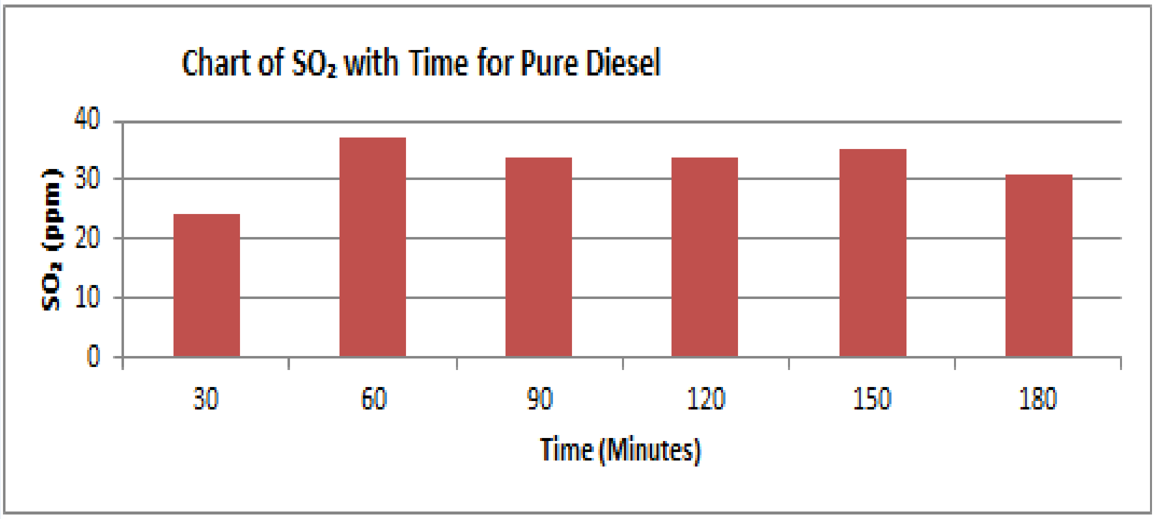

Fig.10: Graph of SO_2 with Time for Pure Diesel

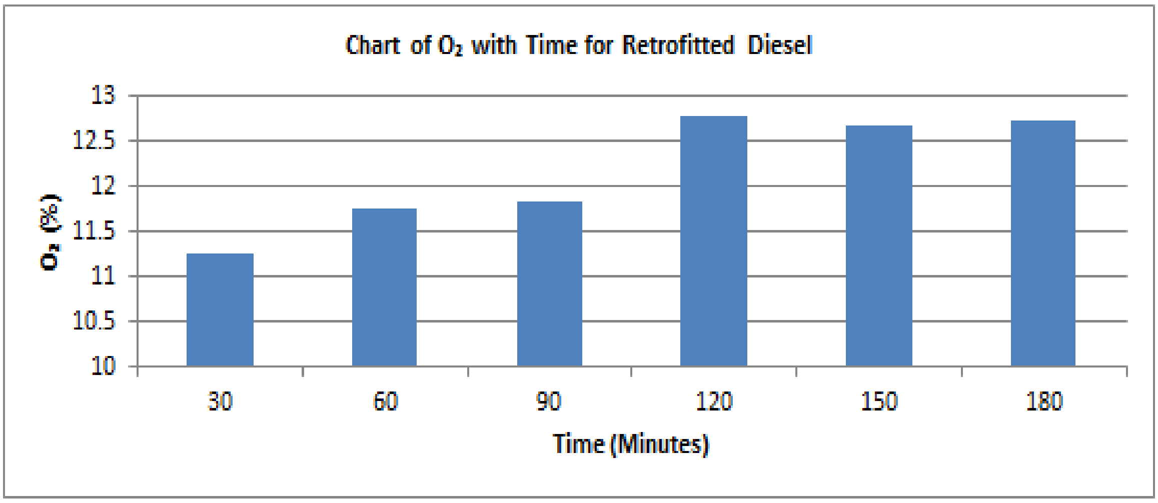

Fig. 11: Graph of O_2 with Time for Retrofitted Diesel

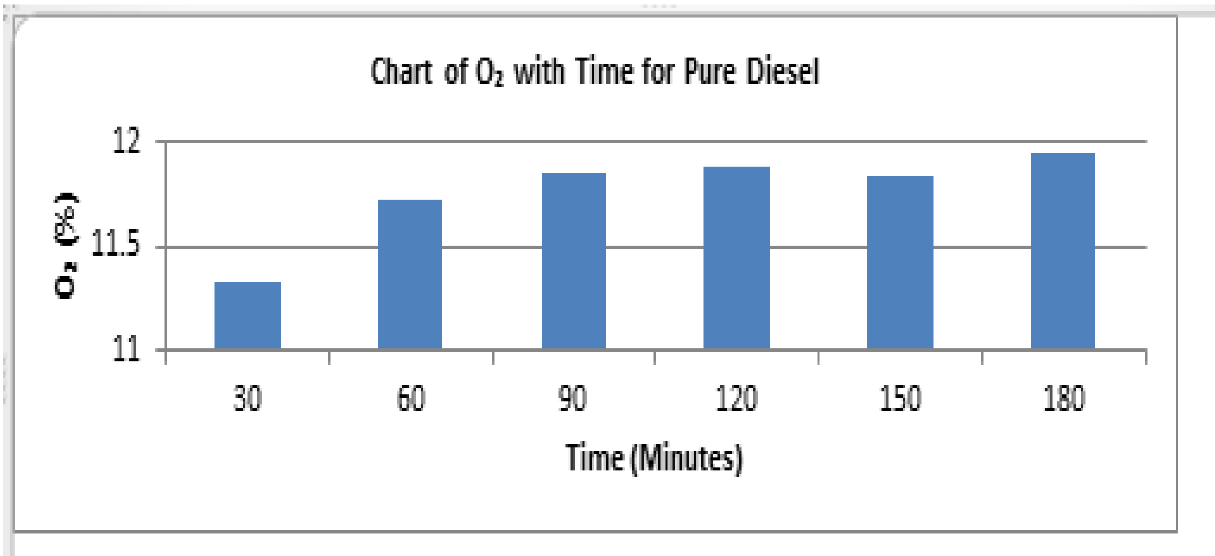

Fig. 12: Graph of O_2 with Time for Pure Diesel

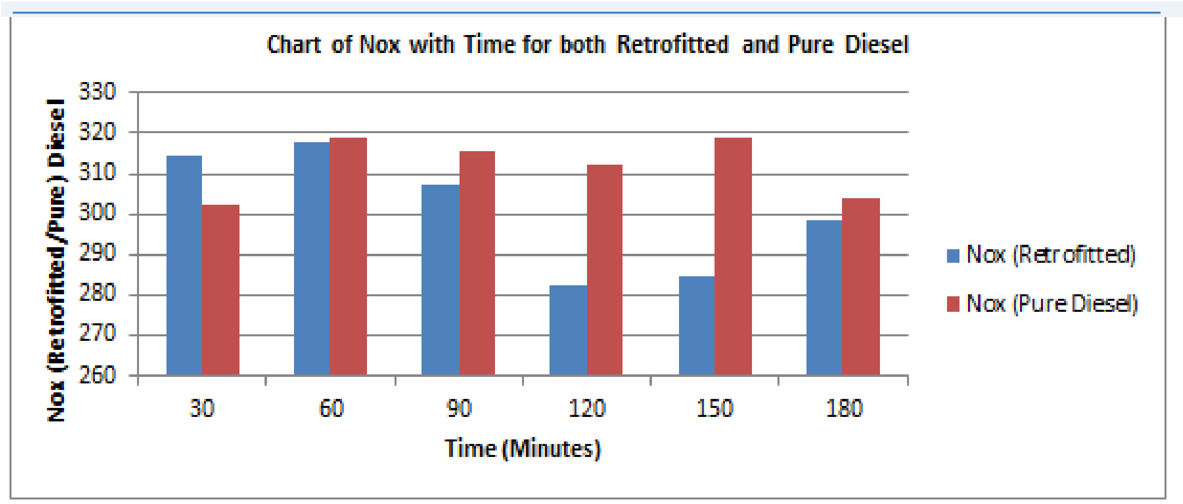

Fig. 13: Graph of NOx Emission with Time for Retrofitted and Pure Diesel

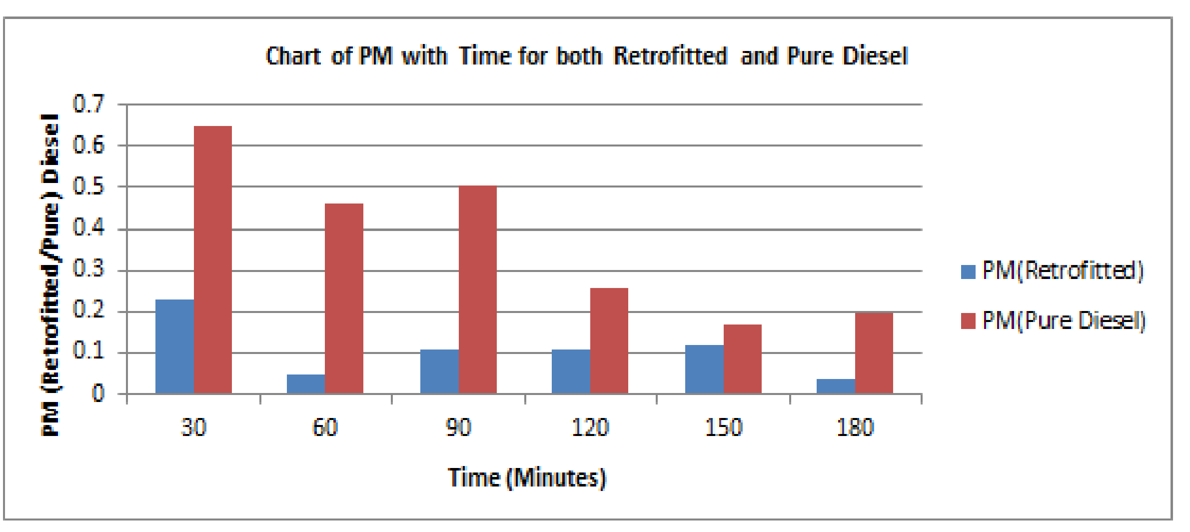

Fig. 14: Graph of PM Emission with Time for Retrofitted and Pure Diesel

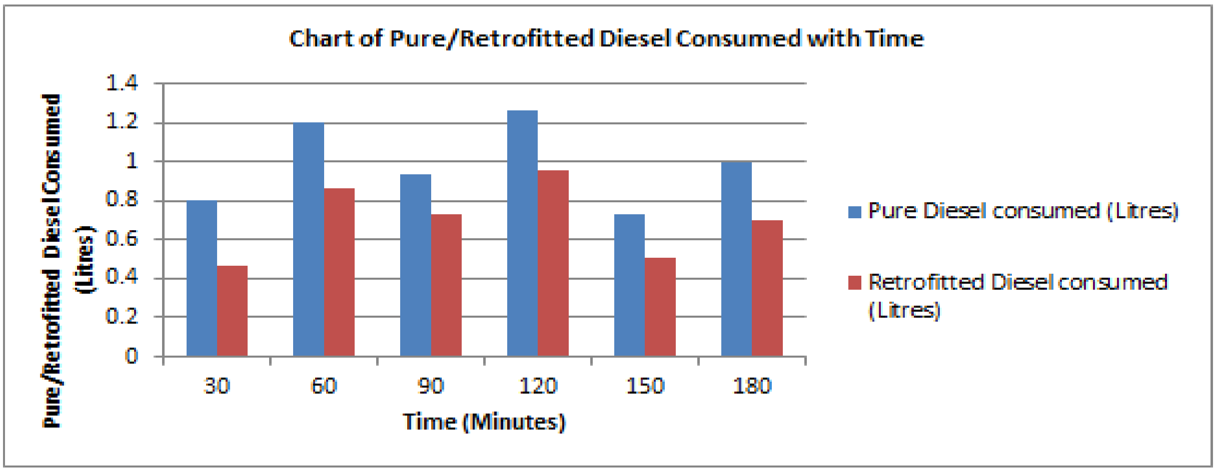

Fig. 15: Graph of Pure / Retrofitted Diesel Consumed with Time

III DISCUSSION OF RESULT

From tables 1 and 2, it was shown that as the ambient temperature reduces the emission rates of PM, CO and NOx also reduce. Also, as the run time increase the ambient temperature and emissions of PM and NOx decrease. Comparing these tables, there was a remarkable reduction in emission of PM and NOx when retrofitted diesel was used to run the generator. In table 3, as the run time increased, the consumption rate on both retrofitted and pure diesel reduces with more noticeable reduction when retrofitted diesel was used. Figure 1 has shown a remarkable reduction in PM emission when XFT retrofitted diesel was used compared with figure 2 which has a high PM emission with pure diesel. There was a marginal difference between the emission rate of NOx pollutants when retrofitted diesel and pure diesel are used as shown in figure 3 and 4. Moreover, figures 5 and 6 have shown that on both occasions there are rise and fall in the emission of CO_2 but on the average there was appreciable reduction in CO_2 emission when retrofitted diesel was used. On figures 7 and 8, the effect of using XFT retrofit resulted in reduction of CO emission as compared with pure diesel. As shown in figures 9 and 10, there was an initial rise in SO_2 emission when retrofitted diesel was used compared with pure diesel but on the average as time progresses a remarkable reduction in SO_2 was recoded with XFT retrofitted diesel. In figures 11 and 12, it has shown that XFT retrofitted diesel generator emitted more O_2 to the environment than pure diesel generator. Figures 13 and 14 have shown the effect of using XFT retrofit in reducing the emission of both NOx and PM pollutants. Also, figure 15 depicted a reduction in diesel fuel consumed when a retrofitted diesel fuel was used compared with pure diesel.

IV CONCLUSION

1. It has been established that using XFT helped in saving cost due to a reduction in fuel consumption at a rate of 28.9%.

2. There was reduction in emission of PM by 71% using XFT retrofitted diesel

3. Also, XFT retrofitted diesel was responsible for 4% reduction in emission of NOx

4. This work therefore encourages operators, managers, individuals to embrace XFT because of its advantages in cost saving and reduction in fuel consumption.

V RECOMMENDATION

1) All rules and regulations on emission must be adhered to strictly by the manufacture of diesel engine generators.

2) Agencies set up to enforce these rules and regulations as relate to emission from DEG must be seen to be doing their job without compromising.

3) One of the bye-product of chemical reaction between carbon monoxide and the retrofit has been the emission of carbon dioxide. Hence, effort must be made by the government of the day to encourage tree planting in order to reduce the quantity of CO_2 from the atmosphere.

REFERENCES

[1] Gilmore, E.A.; Lave, L.B.; Adams, P.J. The Costs, Air Quality, And Human Health effects of meetng Peak Electricity Demand with Installed Backup Generators; Environ. sci. Technol. 2006.

[2] Johnson P. and P.J. Miller, "Ultrafine Particles: Issues Surrounding Diesel Retrofit Technologies for Particulate Matter Control," NESCAUM White Paper, February 5, 2007.

[3] Stephen D, Preparing an Existing Diesel Power Plant for a Wind Hybrid Retrofit: Lessons learned in the Wales, Alaska, Wind-Diesel Hybrid Power Project Presented at the WINDPOWER 2001 Conference Washington, D.C. 2001.

[4] Chameides, W.L. and E.B. Cowling, The state of the Southern Oxidant Study (SOS): Policy-Relevant Findings in Ozone Pollution Research, 1988-1994. North Carolina State University, April 1995.

[5] Beelen R., Long-term effects of traffic related air pollution on mortality in a Dutch cohort (NLCS-AIR Study). Environment Health Perspectives, 2008, 116(11): 1480-1486.

[6] Stanek L.W., Attributing health effects to apportioned components and sources of particulate matter: an evaluation of collective results. Atmospheric Environment, 2011, 45:5655-5663.

[7] U.S Environmental Protection Agency, Office of Air Quality Planning and Standards, National Air Pollution Emission Trends, 1900-1994, October 1995.

[8] MECA, Retrofitting Emission Controls for Diesel-Powered Vehicles, Revised: November 2014.